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BIOLOGY AND VITAL STATISTICS OF RAINBOW TROUT IN THE FINGER LAKES REGION, NEW YORK[1]

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ABSTRACT

A joint study of the rainbow trout in Cayuga, Seneca, Skaneateles and Canandaigua Lakes, and their major spawning tributaries, was carried on from 1953 to 1957 by the New York State Conservation Department and Cornell University. Substantial populations in these waters are being maintained by natural propagation. Spawning runs were sampled each spring; 2,803 adult fish were examined and tagged, and scale readings were recorded for 2,513. Life history data for the first four years, as well as tag returns and creel-census records for 1957, are summarized.

Large numbers of fry hatched each year in these tributaries. Some also served as satisfactory nursery areas holding many parr for as long as 3 years. This influenced the time spent in lake waters before fish returned to the streams to spawn. As an average, males spawned for the first time at a younger age than females. Few of either sex spawned more than once.

The proportion of these populations taken by stream fishing was much greater than that by lake fishing. Natural mortality was estimated to be about double the loss from angling.

Maintenance and improvement of stream conditions in the spawning tributaries are fundamental to the future of the rainbow trout fishery in the Finger Lakes region. At the same time, the data indicate that the fishery is not fully utilizing the adult populations. Extension of the lake-fishing season into the fall months appears to be the most practical means at present of fostering an increased harvest.

Rainbow trout are abundant in several of the Finger Lakes in central New York. These populations have been maintained largely, if not entirely, by natural propagation since initial introductions in

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the 1880's and subsequent plantings in the 1920's. Skaneateles, Seneca, Keuka, and Canandaigua Lakes support the largest populations at present. Introductions have been essentially unsuccessful in Cayuga Lake. Owasco Lake once supported a large population.

Rayner (1941) discussed the management of rainbow trout in these lakes using data that pertained largely to Skaneateles Lake and Grout Brook. Webster (unpublished) summarized existing information for Cayuga Lake. Hatch (1957) studied the success of natural spawning in several Finger Lakes tributaries.

Other references deal primarily with the distribution of the species in this region. Meek (1889) did not find it in the Cayuga Lake basin in 1885–86. Surface (1899) collected two specimens on lamprey weirs in Cayuga Lake Inlet. Reed and Wright (1909) found it "fairly common in the [Cayuga] lake inlet and its tributaries". Greeley (1928) reported rainbow trout in Skaneateles, Owasco, Cayuga, Seneca, Keuka, and Canandaigua Lakes. Rayner (1941) also reported their presence in these six lakes. The same distribution obtains at the present time.

From 1953 to 1957 the New York State Conservation Department and Cornell University carried on a cooperative study of rainbow trout in Skaneateles, Seneca and Keuka Lakes and their respective tributaries Grout Brook, Catherine Creek and Cold Brook. Life history data for the first four years, as well as tag returns and creel-census records for 1957, are summarized in this paper. The Conservation Department made an independent study of Naples Creek and Canandaigua Lake, and data from it are also included. Management implications of the findings are discussed.

MATERIALS AND METHODS

Fieldwork was concentrated on the spawning runs in spring, but data on parr populations were collected throughout the year and some observations were made at other seasons.

Study Area

The area covering by this investigation is shown in Figure 1. Both the lakes and their major tributaries were studied.

Lake Environment The Finger Lakes occupy relatively deep valleys having a generally north-south orientation. They lie mostly in the Appalachian plateau, with only their northermost portions extending into the Ontario plain. Relevant features of topography

and morphometry are given in Table 1. As would be expected in heavily glaciated and eroded areas, hanging valleys, gorges, waterfalls, and relatively steep slopes are common. Many streams along the east and west shores have impassable falls near their mouths. Rainbow trout runs are mainly restricted to the major inlets at the southern ends of the lakes.

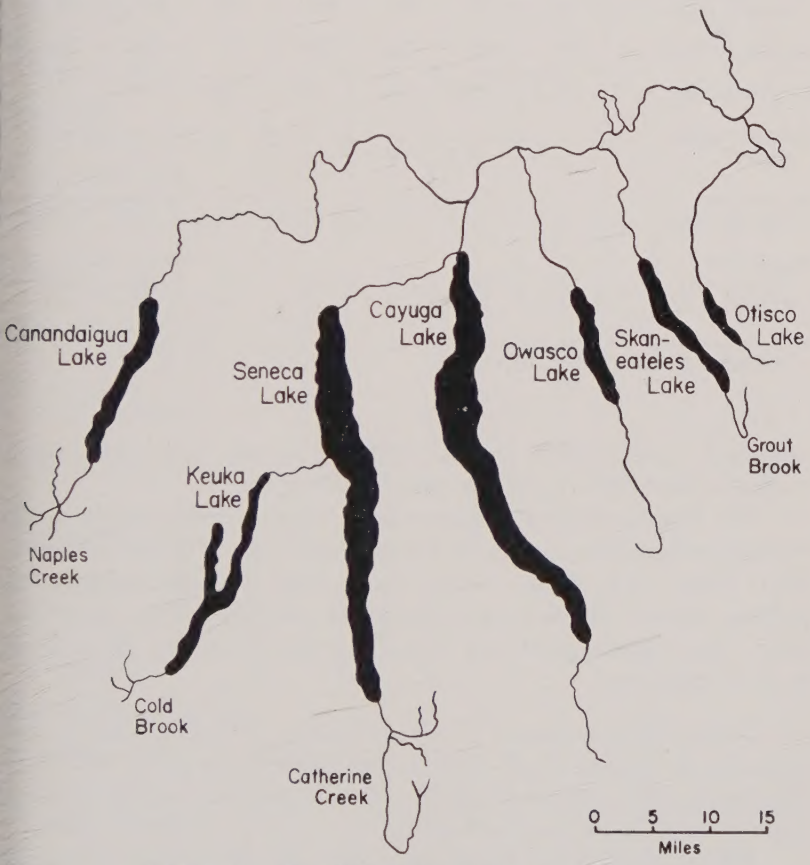

Figure 1. The Finger Lakes of New York State.

The six Finger Lakes that support rainbow trout populations are oligotrophic; comparatively shallow Otisco Lake falls outside this category. They are characterized by abundant oxygen at all depths and by low bottom-water temperatures during the summer (Burkholder, 1931; Henson, 1954). Waters in all six lakes are slightly alkaline, with a pH usually between 7 and 8. Greeley (1928) found

TABLE 1. TOPOGRAPHIC AND MORPHOMETRIC FEATURES OF THE FINGER LAKES*

Item	Lake						
	Otisco	Skaneateles	Owasco	Cayuga	Seneca	Keuka	Canandaigua
Drainage area (square miles)	34	73	208	813	707	187	175
Elevation (feet)	784	867	710	381	444	709	686
Length (miles)	5.4	15.0	11.1	38.1	35.1	19.6	15.5
Average width (miles)	0.6	0.9	0.9	1.7	1.9	0.7	1.1
Surface area (square miles)	2.9	13.9	10.3	66.4	67.7	18.1	16.3
Depth (feet)							
Maximum	66	297	177	435	618	183	274
Mean	6.3	27.0	18.2	33.9	55.1	19.0	24.1

* After Birge and Juday (1914).

numerous representatives of what might be termed "cold water" and "warm water" fishes in all but Otisco Lake (Table 2).

The lake lamprey (*Petromyzon marinus*) merits special mention. It is known to have been present in Cauyga Lake since 1875 and in Seneca Lake since 1894 (Gage, 1928). Scars and wounds, evidence of parasite attacks, are frequently found on lake trout from these two lakes. But exactly what role it plays in the life history of rainbow trout is unknown.

STREAM ENVIRONMENT Grout Brook, Catherine Creek, and Cold Brook (Figure 2) all drain rather limited watersheds and flow into the southern ends of the lakes. Sizable spawning runs of rainbow trout enter these streams each spring.

Salient features of topography for each stream are given in Table 3. The gradients are sufficient in all streams to produce a rapid flow, except in the Catherine Creek canal from Montour Falls to Seneca Lake. The bottom type is generally rubble, ranging from sand and small gravel to boulders.

Wagner (1928) conducted the only known chemical study on these streams in the summer of 1927. The waters of all three were almost completely saturated with oxygen and had a pH of about 8.

TABLE 2. DISTRIBUTION OF CERTAIN FISHES IN THE FINGER LAKES*

Species	Lake						
	Otisco	Skaneateles	Owasco	Cayuga	Seneca	Keuka	Canandaigua
Alewife (*Alosa pseudoharengus*)				X	X	X	
Smelt (*Osmerus mordax*)		X	X	X§			X
Lake cisco (*Coregonus artedi*)	X	X	X	X	X	X	X
Common whitefish (*Coregonus clupeaformis*)		X		X	X	X	X
Lake trout (*Cristivomer namaycush*)		X	X	X	X	X	X
Slimy sculpin (*Cottus cognatus*)				X	X	X	X
Rainbow trout (*Salmo gairdneri*)		X	X	X	X	X	X
Carp (*Cyprinus carpio*)	X		X	X	X	X	X
Common bullhead (*Ictalurus nebulosus*)	X	X	X	X	X	X	X
Chain pickerel (*Esox niger*)	X	X	X	X	X	X	X
Yellow perch (*Perca flavescens*)	X	X	X	X	X	X	X
Large-mouthed bass (*Micropterus salmoides*)	X		X	X	X	X	
Common sunfish (*Lepomis gibbosus*)	X		X	X	X	X	X
Rock bass (*Ambloplites rupestris*)	X	X	X	X	X	X	X

* After Greeley (1928).
§ Not included in Greeley's checklist but now known to be present.

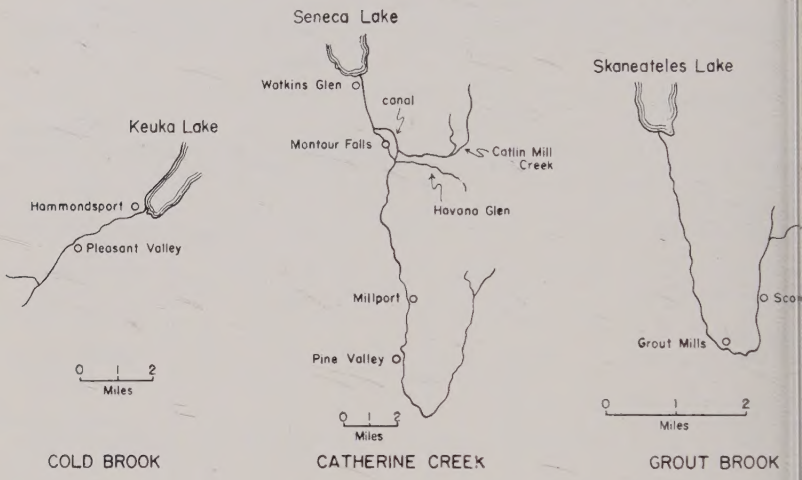

Figure 2. The three major streams studied.

Calcium carbonate hardness was 110 p.p.m. for Grout Brook, 17 p.p.m. for Cold Brook, and 185 p.p.m. for Catherine Creek.

Despite limited watersheds, both Grout Brook and Cold Brook maintain fairly uniform rates of flow throughout the year. Springs between Scott and Grout Mills on Grout Brook, and in the vicinity of the State fish hatchery on Cold Brook, are mainly responsible. Summer water temperatures rarely exceed 65° F., due to spring flow

TABLE 3. TOPOGRAPHIC FEATURES OF THE THREE MAJOR STREAMS STUDIED *

Item	Grout Brook	Catherine Creek	Cold Brook
Total length (miles)	6.5	17	5
Drainage area (square miles)	10	90§	24
Elevation (feet)			
At source	1,700	1,650	1,100
At lake level	875	445	710
Gradient (feet per mile)	127	71	78
Average width (feet)	15	25	10
Summer maximum water temperature	65° F.	85° F.	65° F.

* Derived from United States Geological Survey maps (partly after Hatch, 1957)
§ Excluding Glen Brook.

and shade in the upper portions. Rainbow trout less than 8 inches long are abundantly distributed in both streams throughout the year.

Catherine Creek has a larger watershed, but a greatly reduced flow during the summer months. This is not as true of its tributary Catlin Mill Creek which is partly spring-fed. Besides limited flow, long, open, shallow riffles and lack of shade in some sections contribute to summer water temperatures commonly exceeding 75° F. Few parr are found below Millport in Catherine Creek during the summer. Cooler waters at Pine Valley and in Catlin Mill Creek carry some parr over this period, but sampling did not show summer parr populations in any section comparable to those that existed in Grout Brook and Cold Brook.

COLLECTION OF DATA

Spawning populations in Grout Brook, Catherine Creek, and Cold Brook were sampled during the spring from 1953 to 1957. Sampling was done as closely as possible to the peak of migration in mid-March, but not after the fishing season opened on April 1. This presumably provided samples representative of the bulk of the spawning fish. Only the spawning run at Cold Brook in 1956 was so late that it could

TABLE 4. ADULT RAINBOW TROUT PROCESSED DURING SAMPLING OF THE SPRING SPAWNING POPULATIONS IN THREE FINGER LAKES TRIBUTARIES, 1953–1956

Stream	Item	Number				Total
		1953	1954	1955	1956	
Grout Brook	Fish tagged	85	140	193	207	625
	Fish recaptured*	..	3	7	2	12
	Total processed	85	143	200	209	637
Catherine Creek	Fish tagged	281	499	500	396	1,676
	Fish recaptured*	..	9	11	13	33
	Total processed	281	508	511	409	1,709
Cold Brook	Fish tagged	99	100	246	8	453
	Fish recaptured*	..	1	1	2	4
	Total processed	99	101	247	10	457
Total	Fish tagged	465	739	939	611	2,754
	Fish recaptured*	..	13	19	17	49
	Total processed	465	752	958	628	2,803

* Tagged during a previous year.

not be adequately sampled. Fish were captured with direct-curren electrical shocking equipment (Stone and Hartman, 1957).

During the seasons of 1953 to 1956, a total of 2,803 trout were handled (Table 4)[3]. Each fish was processed for biological data tagged with a serially numbered circular mandible tag, and released Records were kept of fish already tagged. Life history data for adult taken from the spawning runs were transcribed to IBM sorting card for analyses. Scales were examined by back projection at a magnification of 41 diameters.

Parr were not tagged, and only lengths and scale samples were taken.

From 1955 to 1957 a creel census was made by State game protectors on each stream during the opening week of fishing (Hartman 1958).

Validity and Reliability of Scale Readings

Scales afford a means of judging age. For rainbow trout this method was used by Greeley (1933) in some Michigan waters, and by Snyder (1938) in Waddell Creek, California. For steelhead trout it was used by Sumner (1948) in Tillamock County, Oregon; by Shapovalov and Taft (1954) in Waddell Creek, California; and by Maher and Larkin (1955) in the Chilliwack River, British Columbia.

Scales of 2,513 adult rainbow trout from spawning populations in Finger Lakes waters (about 90 per cent of the total collected) were examined.[4] Scales of 280 fish were not used for several reasons: no scale samples (14), regenerate scales only (145), extensive marginal erosion (65), and deformed or internally eroded scales (56).

The scale-reading procedure was similar to that of Cable (1956). Scale samples from parr, adults, and recaptured adults were first examined for orientation. Then all scale samples from adults were independently read twice, the reader knowing only the date and stream where the samples were taken. Readings for 355 samples disagreed in some respect. These were examined a third time and the best estimate of age and life history features was assigned. Scale samples from parr were impressed on plastic and read in the same manner as the scales of adults, except they were usually read only once. Figures 3 and illustrate the critia used.

[3] Trout tagged in 1957 were not used in the analyses of life history data, but t returns for these fish are included.

[4] The sample of 10 fish taken in Cold Brook in 1956 is not included in this or any subsequent analysis unless specifically indicated.

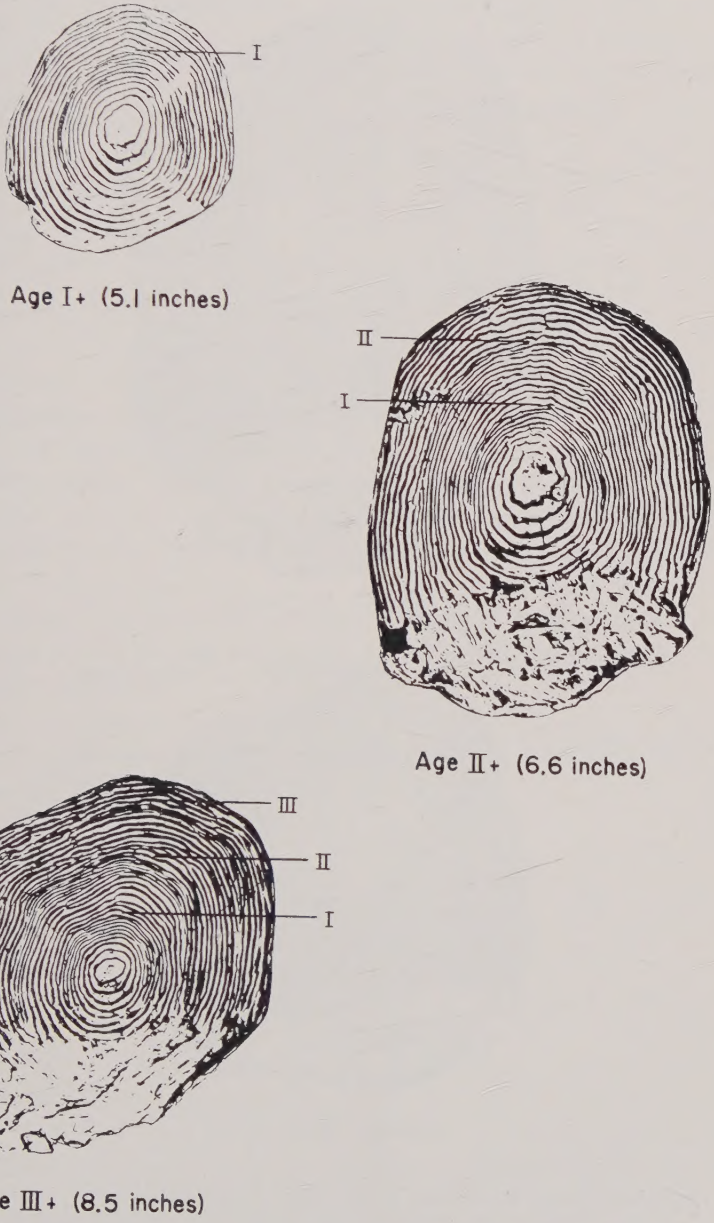

Figure 3. Scales of rainbow trout parr taken from Grout Brook August 9, 1955. (magnified 32 diameters)

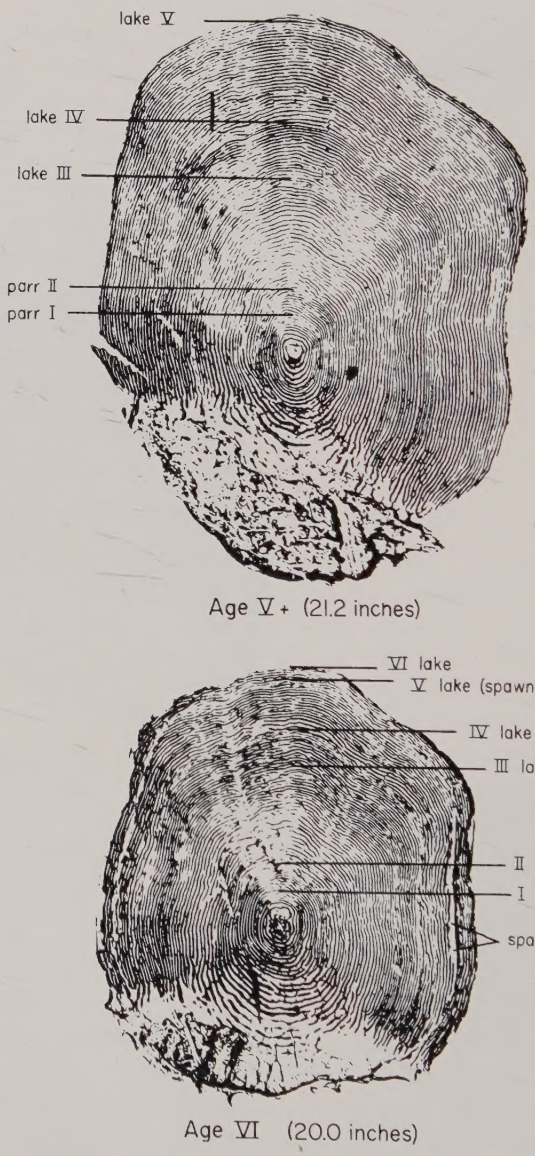

Figure 4. Scales of rainbow trout: (above) first-spawning female taken from Cold Brook March 17, 1955; (below) second-spawning female taken from Grout Brook March 16, 1956. (magnified 14 diameters)

Annuli were recognized by the usual criteria: zones of narrowly spaced circuli, incomplete circuli, and cutting-over of circuli previously laid down. Scales of most fish taken in late March showed marginal annuli. This compares with annulus formation for rainbow trout in Michigan in the winter (Greeley, 1933); and for steelhead trout, in Waddell Creek in January and February (Snyder, 1938), and in the Chilliwack River in March (Maher and Larkin, 1955). Annulus formation was incomplete for some Grout Brook fish. In these cases marginal annuli were assumed in designating age, to provide consistency in assigning fish to proper age groups.

Previous spawnings were recognized by erosion and large, clear streaks in the anterior and lateral fields of the scales. Extreme cutting around circuli often occurred in the posterior field. Since spawning takes place near the time of annulus formation, erosion often obliterated annuli. When this happened the spawning mark was considered to have replaced the annulus as the year mark.

Early years of slow growth with narrowly spaced circuli were distinguished from succeeding years of rapid growth showing widely spaced circuli.

Validity of Scale Readings Validity is considered the soundness of interpreting a scale feature to represent some particular life history feature.

Table 5. Length Frequencies Among Rainbow Trout of Different Ages in the Spawning Populations in Grout Brook, 1953–1956; Annual Samples Combined

Inch group	Age group						
	II	III	IV	V	VI	VII	VIII
11	1	4	..	..	..	..	..
12	..	24	4	..	..	..	..
13	..	36	13	..	..	..	..
14	..	32	67	1	..	..	..
15	..	5	38	..	..	..	..
16	..	..	20	4	..	..	..
17	..	..	22	11	..	..	..
18	..	..	27	56	4	..	..
19	..	..	13	69	9	..	1
20	..	..	1	27	19	3	..
21	..	..	..	5	12	8	1
22	..	..	..	2	3	1	1
23	..	..	..	1	1	..	..
Total	1	101	205	176	48	12	3

Direct validation of the annulus was limited to scale analyses of the 49 adult fish recaptured one, two, or three years after tagging. In only one case did the scale reading disagree with the expected increase in total age. Several types of indirect evidence support the validity of the annulus. The average size of spawning fish in all three streams clearly and consistently increased with age (Tables 5, 6 and 7). Modes in length-frequency distributions of young fish coincide with those for the same fish divided into age groups based on scale readings (Figure 5).

Scales from the 49 recaptured fish clearly supported the interpretation of spawning marks. All but one sample showed a spawning mark laid down during the spring when the fish had been tagged in the spawning population.

Slow growth during their early years as shown on scales of adult

Table 6. Length Frequencies Among Rainbow Trout of Different Ages in the Spawning Populations in Catherine Creek, 1953–1956; Annual Samples Combined

Inch group	Age group						
	II	III	IV	V	VI	VII	VIII
8	1	..	..	..	..	..	..
9	1	..	..	..	..	..	..
10	1	7	..	..	..	..	..
11	4	31	..	..	..	..	..
12	5	88	1	..	..	..	..
13	2	112	7	..	..	..	..
14	1	74	23	..	..	..	..
15	..	32	26	..	..	..	..
16	..	11	38	..	..	..	..
17	..	5	60	2	..	..	..
18	..	..	77	2	..	..	..
19	..	..	107	16	..	..	..
20	..	..	114	17	1	..	..
21	..	..	97	22	..	..	..
22	..	..	62	63	..	..	..
23	..	..	37	51	2	..	..
24	..	..	24	62	3	..	..
25	..	..	6	56	9	..	..
26	..	..	2	55	16	2	..
27	..	..	..	22	24	3	1
28	..	..	..	15	20	4	..
29	..	..	..	4	22	5	1
30	..	..	..	..	6	4	..
31	..	..	..	..	3	2	..
32	..	..	..	..	..	..	1
Total	15	360	681	387	106	20	3

TABLE 7. LENGTH FREQUENCIES AMONG RAINBOW TROUT OF DIFFERENT AGES IN THE SPAWNING POPULATIONS IN COLD BROOK, 1953–1955; ANNUAL SAMPLES COMBINED

Inch group	Age group					
	III	IV	V	VI	VII	VIII
11	3	..	..	..	..	..
12	2	2	..	..	..	..
13	8	7	..	..	..	..
14	11	11	1	..	..	..
15	3	36	3	..	..	..
16	1	26	6	1	..	..
17	..	15	7	1	..	..
18	..	8	16	3	..	..
19	..	13	19	4	..	..
20	..	11	35	7	..	..
21	..	5	37	6	..	..
22	..	2	19	8	1	..
23	..	2	16	9	1	..
24	..	1	3	3	3	1
25	..	..	4	3	1	..
26	..	..	1	..	..	..
27	..	..	1	1	1	1
28	..	..	..	..	1	..
Total	28	139	168	46	8	2

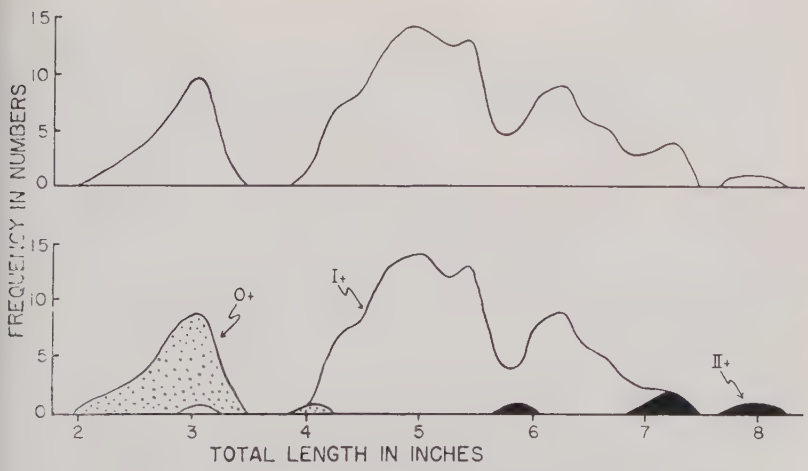

Figure 5. Length-frequency distributions: (above) of 163 parr as a whole; (below) of the same fish divided into age groups. Sample from Cold Brook August 17, 1956. Lengths grouped by 0.2-inch intervals.

fish was similar to growth as shown on scales of parr. Scales indicating rapid growth during the second or third years showed proportionally greater growth than scales of parr. It may be reasonably assumed that, for adult trout from Grout Brook and Cold Brook (both of which support large populations of O+, I+, and II+ parr, and in which fry migrations to the lakes are apparently minor), early years of slow growth represent parr life, and later years of rapid growth represent lake life. The situation in Catherine Creek is discussed later.

Reliability of Scale Readings Reliability is considered the degree of consistency in recognizing specific scale features. Agreement between two independent readings of the 2,513 scale samples from adult trout is given in Table 8. The percentages were consistently high for all three streams. A trend toward slightly lower degrees of agreement for total age among older fish was not considered serious enough to necessitate qualifications when age groups are compared.

Table 8. Percentage Agreement Between Two Independent Readings of the Scales of Adult Rainbow Trout from Spawning Populations in Three Finger Lakes Tributaries

Item	Grout Brook	Catherine Creek	Cold Brook	Combined
Total age	87	91	89	90
Years of slow growth	97	96	92	96
Years of rapid growth	88	91	91	90
Number of spawnings	96	95	97	95
Life history categories	84	87	85	86
Number read	546	1,575	392	2,513

Scale samples from 487 parr captured in different streams and different months of the year were independently read twice to determine the reliability of aging; agreement was 97 per cent.

CHARACTERISTICS OF THE PARR POPULATIONS

Rainbow trout parr behave differently in different streams. This affects the composition of the spawning populations.

Fry Emergence and Movement

Hatch (1957) followed development of rainbow trout eggs spawned in March and April, 1955, in Grout Brook, Catherine Creek, and Cold Brook. Eggs generally reached the eyed stage during May. First fry emergence in Grout Brook took place during the last 10 days in May. Fry were abundant in Catherine Creek and Cold Brook by the first week in June. In 1956, first fry emergence took place May 28 to June 3 in Catherine Creek, June 4 13 in Cold Brook, and June 9 18 in Grout Brook. In 1957, the dates were May 24 27 for Catherine Creek.

The relative magnitude and extent of downstream movement of fry in each stream were determined by overnight trapping of fry simultaneously at different locations. Simple box traps fitted with downstream funnels were placed directly in the current (Figure 6). Rock leaders faced with flat rocks in a shingle fashion were constructed upstream from both front corners of the traps, in many instances extending nearly the full width of the stream. Observations indicated that these diversions were efficient in directing fry to the trap.

The magnitude and extent of upstream movement of fry are considered to be very limited, although no direct attempts at measurement were made. All night observations with a light showed fry either maintaining their stream positions or moving downstream. Frightened fry moved downstream.

Figure 6. Trap for detecting downstream movement of fry, showing placement and rock leaders.

Observations in 1955 and 1956 suggested that fry movements took place chiefly between 11p.m. and 2 a.m. Traps were usually fished from 9 p.m. until 6 a.m.

The data for fry taken during overnight trapping are summarized in Table 9. Despite some sizable downstream movements in the upper and middle sections of Grout Brook, no more than five fry were trapped in one night at a station 400 yards above Skaneateles Lake. Fry were never observed to be abundant in that area. It seems reasonable to conclude that fry generally drifted downstream from the upper section where spawning was heavy and took up residence in less crowded sections downstream. Large fry migrations were never detected near the lake.

Evidence of this nature is less conclusive for Cold Brook. No sizable fry migrations were detected in any section in either 1955 or 1956. The few fry trapped could easily represent just random movement.

Inventories at both streams in August and December of both years provided definite evidence that large numbers of fry had taken up residence. Many from previous year classes were present as O+, I+ and II+ parr.

Overnight fry catches in Catherine Creek were low. This may have been due to ineffective means of trapping fry in a stream of this size. Night observations during 1956 revealed the first fry emergence in the section above Millport on June 3, and in the section between Millport and Montour Falls on June 8; spawning was heavy in both sections. On June 8 and subsequent nights, fry were also observed throughout the sections at Millport where no spawning occurred, but evidence of sizable fry migrations is again inconclusive.

Large numbers of fry were captured leaving Havana Glen and entering Catherine Creek at Montour Falls shortly after emergence. Presumably fry from this tributary move half a mile downstream to the canal. Movement of fry once they reached the canal below Montour Falls was not successfully traced. Observations and seining were conducted on nine nights in 1957 after fry emergence commenced. However, no fry were observed or captured in the canal or in Seneca Lake at the canal's mouth, presumably because of ineffective means of sampling.

The likelihood of large fry migrations to Seneca Lake after emergence in both Catherine Creek and Havana Glen is supported by indirect evidence. August and December inventories of parr showed that very few fry remained in the main stream or Havana Glen. Th

TABLE 9. FRY CATCH DURING OVERNIGHT TRAPPING IN THREE FINGER LAKES TRIBUTARIES IN JUNE AND JULY, 1955–1956

Year	Night	Upper section	Middle section	Lower section	Havana Glen
Grout Brook					
1955	June 5	338	9	0	xx
	10	650*	134	1	xx
	19	104	..	5	xx
	19	124	..	..	xx
	July 15	6	..	0	xx
1956	June 18	14	39	..	xx
	25	127	..	0	xx
	25	0	..	..	xx
	30	0	..	..	xx
	30	45	16	0	xx
	July 13	5	4	0	xx
	31	2	1	0	xx
	31	0	..	..	xx
Catherine Creek					
1955	June 8	2	8	1	..
1956	June 3	3	..	..	..
	6	6	..	0	2
	8	11	0	1	41
	10	..	..	..	94
	11	60	3	6	458
	12	25	..	..	318
	14	1	..	1	94
	16	2	..	0	29
	19	0	..	0	..
	26	0	..	0	4
	28	..	..	0	..
	July 2	..	..	1	1
	5	0	..	0	0
Cold Brook					
1955	June 6	13	6	0	xx
	28	1	10	..	xx
1956	June 13	9	31	..	xx
	13	..	12	..	xx
	19	0	11	..	xx
	28	2	24	..	xx
	28	..	19	..	xx

* Estimated.

few O+ parr captured were restricted to the cooler headwaters i Pine Valley and the spring-fed Catlin Mill Creek tributary.

Distribution and Relative Abundance of Parr

Observations at Grout Brook and Cold Brook, during samplin of the spawning populations, the fry populations and the parr popu lations, have shown parr to be distributed abundantly throughout both streams at all times of the year.

Parr populations were quantitatively sampled in August 1955. Stream sections, usually two at each of several locations on each stream, were 200 feet long and were blocked off with ¼-inch-mesh seines. Parr were captured with electrofishing gear previously described. Sampling was limited to two upstream runs through each section. Only 13.4 per cent of the total catch was taken during the second run in 12 sections of Grout Brook, and 13.7 per cent in six sections of Cold Brook. Consistently lower second-run catches suggested that the DeLury (1947) regression method of estimating population size might apply. First- and second-run catches were plotted against the cumulative catch for each section. The intercept on the *X*-axis (cumulative catch) of the regression line through these two points was considered the most reliable estimate of the total parr population in that section. These estimates were not materially higher than the total catch in both runs (Table 10), indicating that the sampling methods employed were quite efficient.

Large numbers of yearling and older parr were estimated to be present in most sections at both streams (Table 10). The limited number of parr in the farthest upstream sections of Grout Brook was due primarily to the small size of the stream in that area; at the time of sampling, most of the flow came from springs about 300 yards above the upper section. Sections farther downstream were physically capable of supporting more parr. Below the headwater region in either stream, where water flow was fairly constant, differences in the number of pools and amount of cover appeared to be more important in governing the number of parr in any section.

Parr were virtually absent in Catherine Creek. A few were observed generally distributed throughout the main stream and its major tributaries in December and March. Summer distribution, however, was restricted to the coolest headwaters in Pine Valley and spring-fed Catlin Mill Creek. In June 1955 only six parr were captured in six 200-foot sections of Catherine Creek between Montour Falls and Pine Valley. None was captured there the following

Table 10. Total Catch and Population Estimates by DeLury Method for Age I+ and Older Parr in 200-foot Stream Sections at Grout Brook and Cold Brook in August 1955

Section	Sample		Total catch	DeLury estimate
	First	Second		
Grout Brook				
I (1)	12	2	14	14
I (2)	31	4	35	36
II (1)	37	9	46	49
III (1)	60	12	72	75
III (2)	71	8	79	80
IV (1)	56	4	60	60
IV (2)	114	8	122	123
V (1)	86	21	107	111
V (2)	154	19	173	175
VI (1)	36	10	46	50
VI (2)	51	13	64	68
Cold Brook				
I (1)	46	4	50	50
I (2)	93	3	96	96
II (1)	100	22	122	128
II (2)	118	20	138	145
III (1)	84	28	112	126
III (2)	72	4	76	76

August. Parr were captured in Catlin Mill Creek in both June and August of 1955 and 1956.

Although the sampling program was not designed to estimate total parr populations, some rough idea of their magnitude was derived from the data. Approximately 4.5 miles in each of Grout and Cold Brooks held parr in August 1955. The average number of parr per 200-foot section was estimated as 77 in Grout Brook and 104 in Cold Brook. Expansion of these values yields estimated total populations of about 9,000 and 12,000, respectively.

Age and Growth

Parr populations in various stream locations at Grout Brook and Cold Brook were inventoried during June, August, and December of 1955 and 1956. The large numbers of newly emerged fry were not included in June samples. Except for a limited sample from Cold

Brook, O+ parr were arbitrarily excluded from the August 1955 samples (designed primarily to estimate the relative abundance of I+ and older parr). However, O+ parr were included in the August 1956 samples to evaluate their relative importance in the structure of the parr populations at that time of year.

It seems valid to combine samples from different stream locations in growth and age-group analyses. Rarely did differences between locations in mean lengths for O+ and I+ parr exceed 0.2 inch. It was observed in the August (1955) inventories that paired samples of I+ parr from similar locations often showed this much or more variation. Relative proportions of different age groups also were fairly consistent between locations.

The pattern of length-frequency distributions of the age groups of parr was generally similar in the samples for both streams and is illustrated in Figure 7 for Grout Brook. Age I+ parr were relatively important in both streams; they were quite comparable to O+ parr in December 1955 in Grout Brook, and in August and December, 1956 in both streams. Only in June and August, 1955 were II+ parr important in relation to the abundance of I+ parr. This may have reflected relative year-class strength.

Polymodal distributions for some year classes persisted for several sampling periods (e.g., the trimodal distribution of O+ parr in Grout Brook in December 1955, and of I+ parr throughout 1956). It was frequently observed that minor spawning runs occurred at times other than that of the major run. These modes may have reflected different fry hatches. The modes persisted in adequate samples from different stream locations.

Most growth was made between the December and June samplings (presumably in the spring). Also length-frequency distributions of specific age groups were quite similar at the same time each year. Finally, the figure shows that the two most important parr groups (O+ and I+) were afforded almost complete protection under the existing minimum size limit of 7 inches for angling, and this was also true for parr in Cold Brook.

Additional features of age and growth for parr in all three streams are compared in Table 11. Figures for Catherine Creek apply chiefly to its Catlin Mill Creek tributary. Data from preliminary sampling in December 1954 are included. Growth of different year classes in each stream was similar. Young parr, O+ and I+, grew slightly better in Cold Brook than in Grout Brook. Growth in Catherine Creek was substantially greater than in the other two streams. This

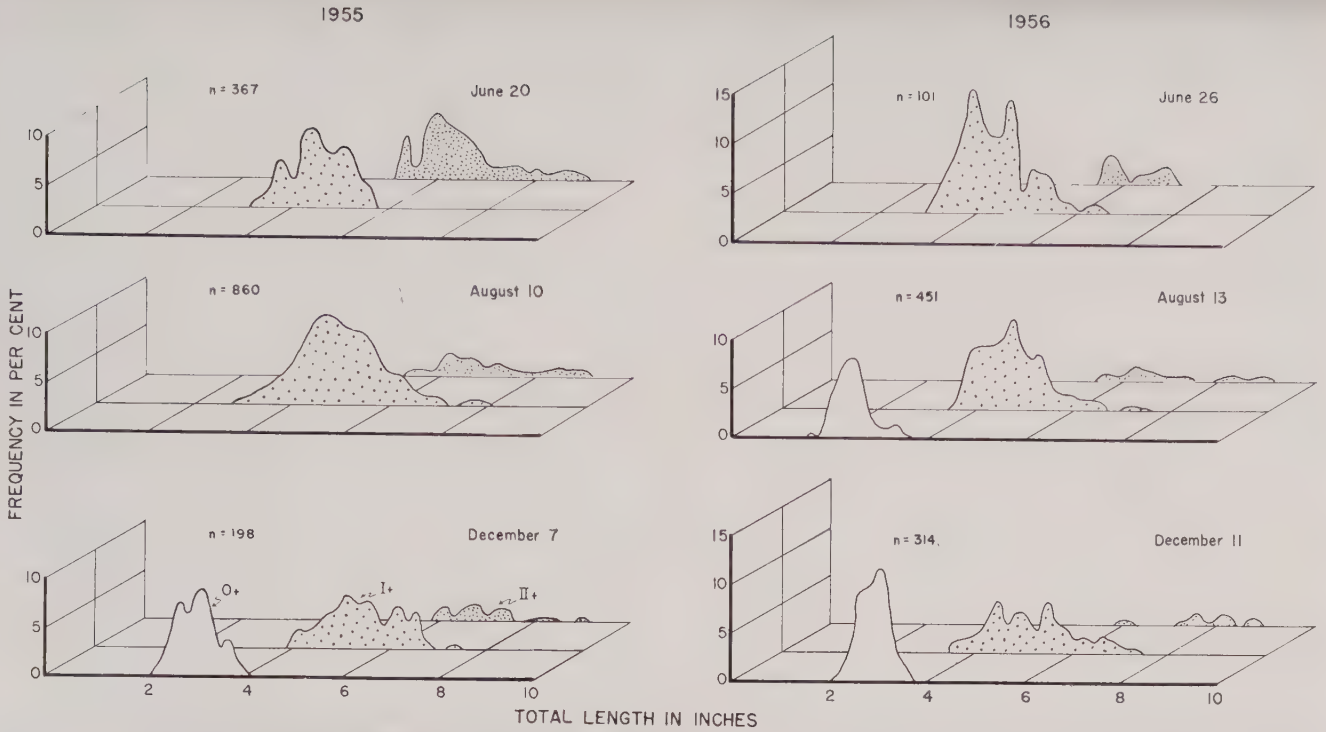

Figure 7. Length-frequency distributions of three age groups of parr at successive times of year. Samples from Grout Brook in 1955 and 1956. Age group 0+ arbitrarily excluded from data for June in both years and for August in 1955.

Table 11. Mean Lengths for Three Age Groups of Parr in June, August and December Samples from Three Finger Lakes Tributaries*

Year class	O+ parr		I+ parr			II+ parr		
	August	December	June	August	December	June	August	December
Grout Brook								
1956	2.4 (135)	2.9 (153)	...	...	...	...	...	...
1955	...	3.0 (90)	4.2 (91)	4.6 (289)	5.1 (147)	...	...	...
1954	...	3.2 (8)	4.4 (196)	4.8 (748)	5.4 (90)	6.1 (10)	6.9 (27)	7.5 (14)
1953	...	...	...	...	5.1 (40)	6.3 (171)	6.8 (112)	7.0 (18)
1952	...	...	...	...	...	...	...	7.7 (4)
Average	2.4 (135)	2.9 (251)	4.4 (287)	4.7 (1,037)	5.2 (277)	6.3 (181)	6.8 (139)	7.3 (36)
Cold Brook								
1956	2.5 (239)	3.3 (288)	...	...	...	...	...	...
1955	3.0 (105)	3.2 (891)	4.9 (285)	5.3 (196)	5.2 (216)	...	...	...
1954	...	3.5 (36)	4.9 (289)	5.3 (398)	5.0 (116)	7.2 (11)	6.5 (16)	7.1 (17)
1953	...	...	...	...	5.7 (25)	6.5 (212)	6.5 (205)	7.1 (50)
Average	2.7 (344)	3.2 (1,215)	4.9 (574)	5.3 (594)	5.2 (357)	6.5 (223)	6.5 (221)	7.1 (67)
Catherine Creek								
1956	...	3.9 (20)	...	...	...	...	...	...
1955	...	3.4 (17)	...	...	6.8 (15)	...	...	...
1954	...	3.2 (18)	6.1 (20)	6.2 (52)	6.4 (1)	...	...	8.4 (1)
1953	...	...	...	...	5.3 (15)	7.0 (6)	7.7 (5)	8.4 (2)
1952	...	...	...	...	...	...	...	7.4 (4)
Average	...	3.5 (55)	6.1 (20)	6.2 (52)	6.1 (31)	7.0 (6)	7.7 (5)	7.8 (7)

* Over-all sampling period extended from December 1954 to December 1956; figures in parentheses represent number of fish in each sample.

may have been the result of less competition and, or warmer water temperatures in Catherine Creek.

Characteristics of the Spawning Populations

Spawning populations were sampled during peaks of the spring migrations, and it is presumed that the samples were sufficient to characterize their major features. Juvenile rainbow trout remaining in the lakes were obviously excluded. For this reason the spawning populations cannot be considered representative of the total lake populations of adult and subadult trout.

For ease in handling the data, spawning populations are usually identified with the stream in which they spawned. However, it is understood that they represent portions of the lake populations.

Various sex, age, and length data are missing for different fish.

Table 12. Age-Frequency Distributions of Rainbow Trout in the Spawning Populations in Three Finger Lakes Tributaries, 1953–1956

Year	Age group						
	II	III	IV	V	VI	VII	VIII
Grout Brook							
1953	..	12	30	30	3	..	..
1954	1	47	38	21	12	4	..
1955	..	33	67	50	18	7	1
1956	..	9	70	75	15	1	2
Total	1	101	205	176	48	12	3
Catherine Creek							
1953	3	98	87	42	26	1	.
1954	3	52	260	108	30	12	..
1955	7	168	99	167	26	1	2
1956	2	44	236	70	24	6	1
Total	15	362	682	387	106	20	3
Cold Brook							
1953	..	4	25	43	15	2	..
1954	..	12	35	38	5	2	..
1955	..	12	80	87	26	4	2
Total	..	28	140	168	46	8	2

Rather than restrict the analyses to specimens with complete data and lose some information, as many records as possible were used in each analysis; thus the totals in various tables do not necessarily agree.

Age

Age affects the nature of spawning populations in several ways.

Age Composition Age frequencies for the annual samples are given in Table 12. Age groups III, IV, and V comprised the bulk of fish in Grout Brook (86 per cent) and Catherine Creek (91 per cent). The relative unimportance of age group III in Cold Brook is apparent as 79 per cent of the spawning fish fell into age groups IV and V. The oldest fish were 8 years old. Older fish in age groups VI through VIII constituted a minor proportion.

A detailed breakdown of these data allows study of specific factors that affect age composition.

Life History Categories A code for recording age and other life history features of spawning rainbow trout was developed after Shapovalov and Taft (1954). Arabic numerals and symbols were used in the formula for each fish as follows:

/ separates years of parr life from years of lake life

. used in formulae for spawners to separate years of lake life when no spawning occurred from years of lake life when spawning occurred

S represents repeat spawners; follows numeral that denotes the total number of spawnings

Total age is determined by adding all numerals in the formula as in the following examples.

Formula	Translation
2/1	3-year-old maiden spawner, two years of parr life, and one year of lake life
2/2S	4-year-old second spawner, two parr years and two lake years
1/2.3S	6-year-old third spawner, one parr year and five lake years

Spawning populations in each stream embodied a multiplicity of life history categories with different combinations of parr and lake life. Twenty-nine categories were represented at Grout Brook, 28 at Cold Brook, and 33 at Catherine Creek. They ranged from 1/1 to 4/2 and 1/2.5S. The range of categories among first spawners is given in Figure 8.

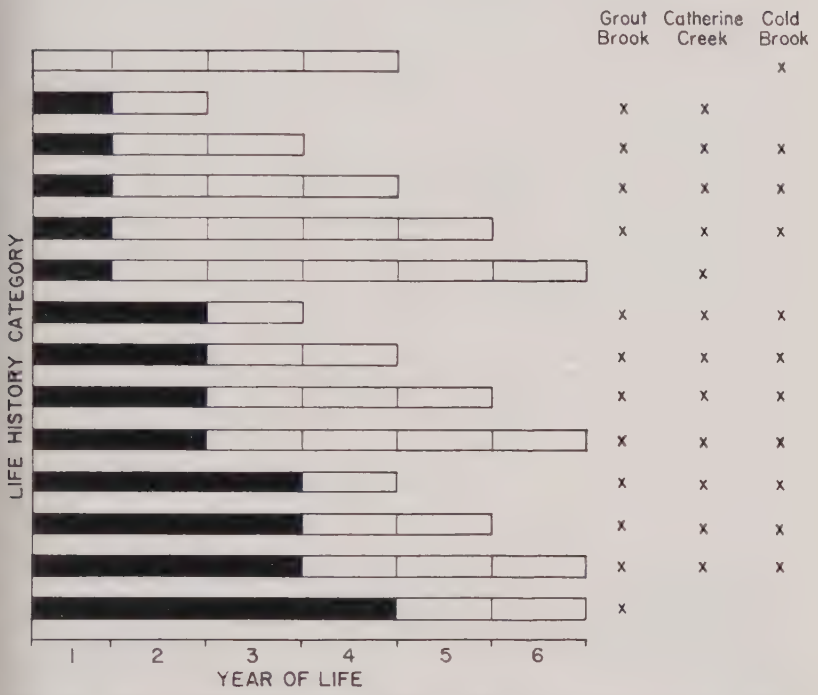

Figure 8. Range of life history categories for first-spawning rainbow trout in three Finger Lakes tributaries, 1953–1956. Solid portions of bars represent parr life; open portions, lake life.

Despite the great diversity of categories for each stream, only a limited number constituted 5 per cent or more of the spawning populations (Table 13). These accounted for about 75 per cent of the total in each stream.

TABLE 13. PERCENTAGES OF THE SPAWNING POPULATIONS IN THREE FINGER LAKES TRIBUTARIES ACCOUNTED FOR BY THE DOMINANT LIFE HISTORY CATEGORIES, 1953–1956; ANNUAL SAMPLES COMBINED

Stream	Life history category									Total
	1/2	2/1	1/3	2/2	1/4	2/3	1/2.2S	2/1.2S	2/2.2S	
Grout Brook	5.2	12.8	8.3	22.6	....	22.1	....	....	5.0	76.0
Catherine Creek	20.9	....	34.5	....	5.6	....	12.0	....	....	73.0
Cold Brook	6.6	....	12.5	18.6	5.6	24.5	....	6.1	....	73.9

Dominant categories in Grout Brook and Cold Brook were heavily represented by 2-year parr. It has previously been noted that parr populations were very important at these two streams. On the other hand, dominant categories in Catherine Creek were entirely composed of fish with one early year of slow growth. Parr populations in Catherine Creek were probably quite unimportant in maintaining the spawning populations. Even though the one early year of slow growth of most adult Catherine Creek fish likely took place in Seneca Lake, for convenience in discussing fish from all three streams the early, slow-growing year or years are denoted as parr life.

Sex Composition Most young fish were males, and most old fish were females (Figure 9). This obtained in all samples. Males obviously entered the spawning populations at an earlier age.

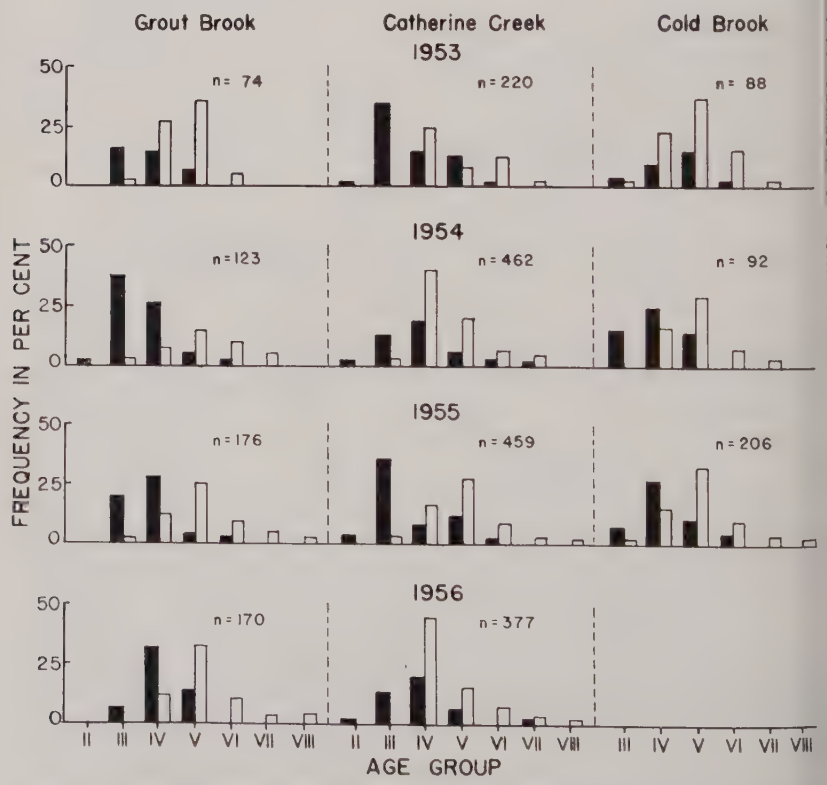

Figure 9. Yearly age-frequency distributions of males (solid bars) and females (open bars) in the spawning populations in three Finger Lakes tributaries, 1953-1956. Percentages based on total numbers of specimens.

Sex composition may be further analyzed by considering age at maturity, since interpretation of spawning marks on scales was previously shown to be reliable.

Age at Maturity Fish with no evidence of previous spawning on their scales were considered as maiden fish or first spawners. The percentages of maiden fish of each sex occurring in different age groups are given in Figure 10. Males mature at an earlier age than females, and maturation for most fish of either sex takes place over two years. In Grout Brook, maiden males in the spawning populations occurred rather evenly in age groups III and IV, maiden females in groups IV and V. Most males in Catherine Creek first appeared

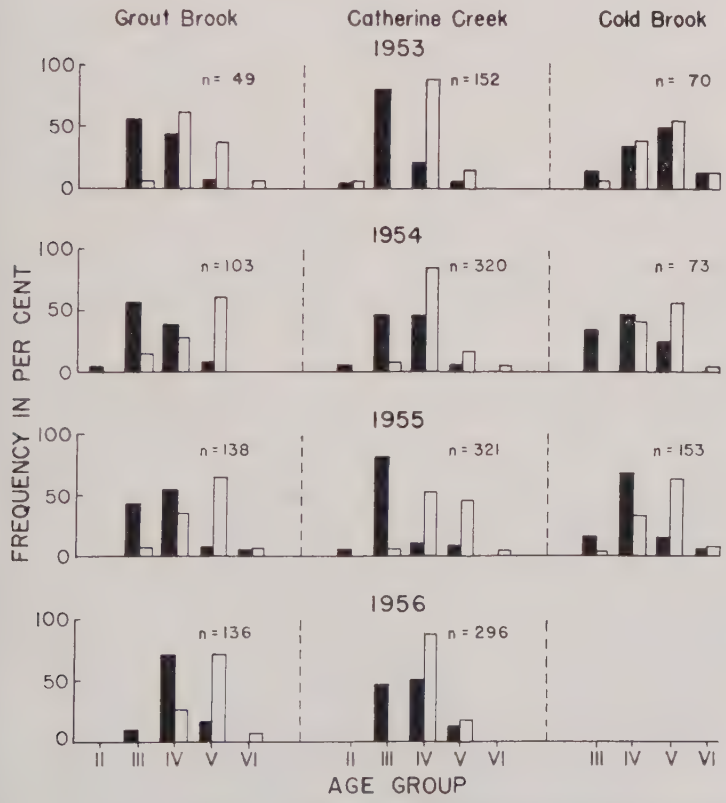

Figure 10. Yearly age-frequency distributions of maiden males (solid bars) and females (open bars) in the spawning populations in three Finger Lakes tributaries, 1953–1956. Percentages based on total numbers of each sex tagged.

in age groups III and IV, with an indication that the younger age group predominated in some years. Maiden females were more frequent in age group IV than in V. In Cold Brook, males first occurred strongly in age group IV, with large numbers occasionally entering in age groups III and V. Females predominated in age groups IV and V.

A relationship existed between the early life history and the age when fish first appeared in the spawning populations. Percentages of

Table 14. Percentage Age-Frequency Distributions of Maiden Males and Females, with Different Numbers of Parr Years, in the Spawning Populations in Three Finger Lakes Tributaries, 1953–1956; Annual Samples Combined

Age group	Years of parr life								
	Male				Female				
	0	1	2	3	0	1	2	3	4
Grout Brook									
II	..	3	..	..	..	..	..	..	..
III	..	59	38	..	..	8	2	..	..
IV	..	34	53	88	..	82	21	18	..
V	..	4	8	6	..	10	76	36	..
VI	..	..	1	6	..	..	1	46	100
Sample size	..	44	177	14	..	38	141	11	1
Catherine Creek									
II	..	3	..	..	..	..	..	..	..
III	..	71	30	..	..	1	4	..	..
IV	..	22	56	75	..	85	19	67	..
V	..	4	12	25	..	13	76	..	..
VI	..	..	2	..	..	1	1	33	..
Sample size	..	418	73	4	..	518	75	3	..
Cold Brook									
III	..	66	..	..	..	2	1	..	..
IV	100	24	69	33	100	67	17	11	..
V	..	10	29	17	..	31	81	42	..
VI	..	..	2	50	..	..	1	47	..
Sample size	1	38	81	6	2	58	90	19	..

maiden fish with different numbers of parr years, that occurred in each age group, are given in Table 14. For example, 59 per cent of the 44 maiden males from Grout Brook with only one parr year appeared in age group III. In every stream, for both sexes, fish that had undergone only one parr year usually first appeared in the spawning populations at a younger age than fish that had undergone two parr years. Fish that had undergone three parr years appeared in even older age groups, although conclusions are limited by small sample size.

The most plausible explanation seems to be that fish require a certain amount of growth for maturation. Fish with only one year of parr life mature rapidly and appear in the spawning populations at a young age, while maturation and spawning of fish with two or more years of parr life is delayed. This relationship coupled with the noted predominance of fish with only one year of parr life in Catherine Creek, seems to account for the appearance of both sexes at an earlier age in the spawning populations there.

Year-Class Strength Annual differences in age composition at Catherine Creek, evident in Figure 9, seem to have been definitely associated with year-class strength. Maiden males of the 1950 year class predominated in age group III in 1953. Maiden females appeared strongly in age group IV in 1954. In addition, maiden males of this year class, juveniles in 1953, plus repeat spawners from 1953 were strongly represented in age group IV. In 1955, additional maiden females plus repeat spawners appeared strongly in age group V. The relatively weak 1951 year class and the strong 1952 year class may be similarly traced.

Fluctuations in year-class strength are not clearly shown for Grout or Cold Brooks. It has been pointed out that the appearance of maiden fish in the spawning populations in these streams was spread rather evenly over two age groups for each sex, and sometimes three for males in Cold Brook. So any fluctuations in year-class strength that might have been present would have been spread rather evenly over two or more age groups for each sex, and consequently their effects modulated. In Catherine Creek, maiden males predominated in age group III and females in age group IV. Fluctuations in relative year-class strength were more concentrated in a specific age group for each sex, and were more readily detectible.

Repeat Spawners Repeat spawners comprised 18 to 33 per cent of the total spawning populations, but maiden fish dominated in

all instances (Figure 11). Few fish survived to spawn more than once. The record number of spawnings was five for several Catherine Creek fish.

As expected, most repeat spawners were derived from the most strongly represented categories among maiden fish. Data also indicate that females predominated among repeat spawners, i.e., female repeat spawners occurred in greater proportion to males than the proportion that existed between maiden males and females. Differential survival following first spawnings may be inferred from this,

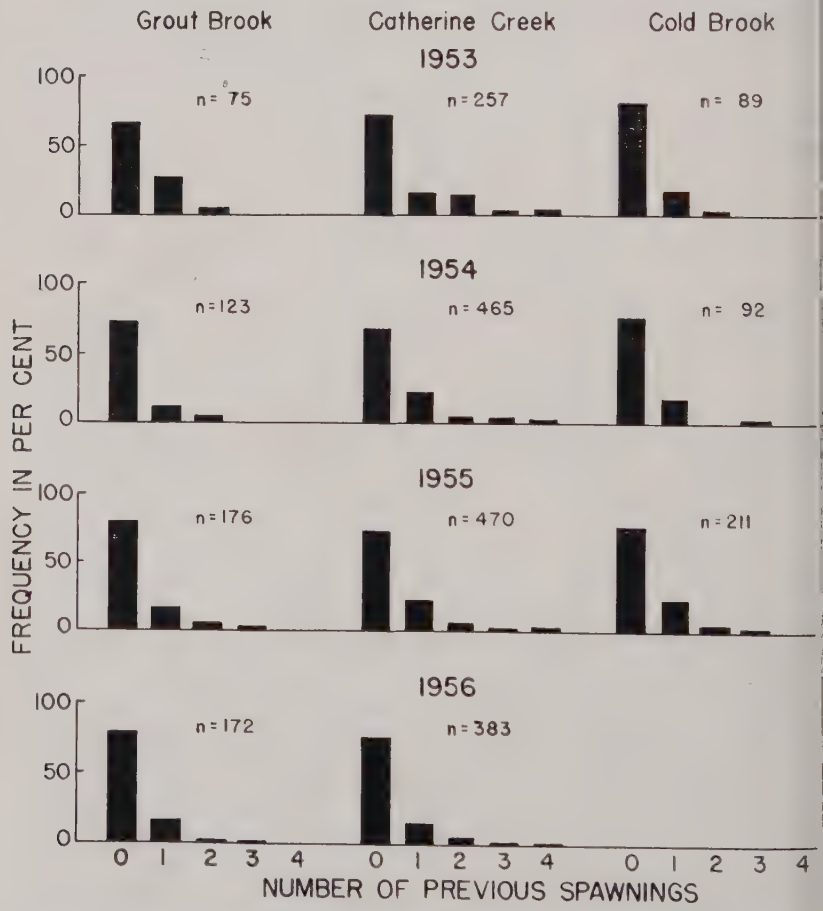

Figure 11. Relative frequency of maiden fish and repeat spawners in the spawning populations in three Finger Lakes tributaries, 1953–1956.

but discussion is deferred until survival rates of the sexes have been considered.

Sex Ratio The frequency of males and females, and the number of males per hundred females, are given in Table 15. Males outnumbered females in 6 of 11 samples. On a stream basis, females

Table 15. Frequency of Males and Females, and the Number of Males per Hundred Females, in the Spawning Populations in Three Finger Lakes Tributaries, 1953–1956

Stream	Year	Frequency in sample		Males per hundred females
		Males	Females	
Grout Brook	1953	31	53	58
	1954	98	45	218
	1955	101	99	102
	1956	106	101	105
	Total	336	298	113
Catherine Creek	1953	144	96	150
	1954	190	315	60
	1955	265	234	113
	1956	153	249	61
	Total	752	894	84
Cold Brook	1953	27	71	38
	1954	52	49	106
	1955	104	137	76
	Total	183	257	71

outnumbered males in Catherine Creek and Cold Brook but not in Grout Brook. Shapovalov and Taft (1954) found female steelhead trout slightly outnumbering males in Waddell Creek. They also observed significant changes in the sex ratio during the spawning season, with males predominating early and females later on. Observations on spawning seasons in the Finger Lakes region also suggest this. Rayner (1941) found an unbalanced sex run (85 males to 158 females) in Grout Brook. He suggested that this was probably due to an early run of predominantly male fish that took place before trapping operations. All data suggest that females slightly predominate in the spawning populations, but changes in the sex ratios during the spawning seasons likely account for the large variations from sample to sample seen in Table 15.

Growth

Several aspects of growth are important in determining the nature of spawning populations.

Length-Frequency Distributions All populations showed bimodal length distributions (Figure 12) for each sex caused by the dominant life history categories. The average and maximum lengths and weights for each sex from each stream are given in Table 16.

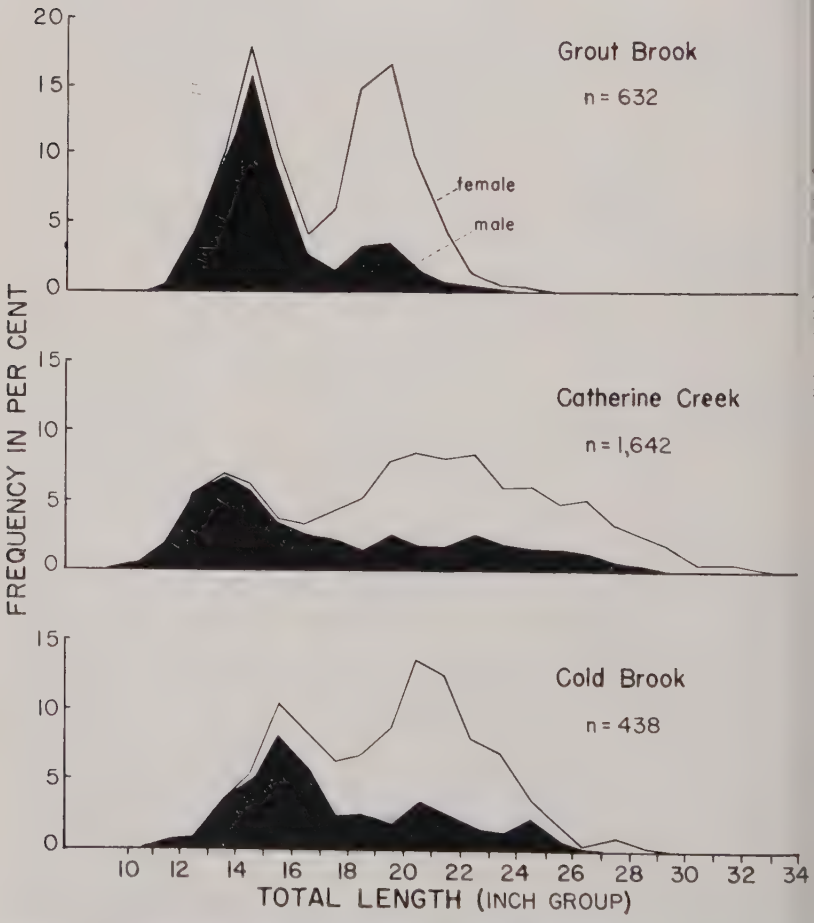

Figure 12. Length-frequency distributions of males and females in the spawning populations in three Finger Lakes tributaries, 1953–1956; annual samples combined.

Table 16. General Growth of Males and Females in the Spawning Populations in Three Finger Lakes Tributaries, 1953–1956; Annual Samples Combined

Stream	Males		Females	
	Mean	Maximum	Mean	Maximum
	Length in inches			
Grout Brook	15.3	23.2	18.9	23.2
Catherine Creek	17.0	31.5	22.7	32.1
Cold Brook	17.3	25.6	19.2	28.4
	Weight in pounds			
Grout Brook	1.4	4.0	2.4	4.3
Catherine Creek	2.3	13.7	5.1	14.8
Cold Brook	2.3	7.6	3.6	10.2

Growth of the Age Group Most age groups spanned considerable ranges in length (Tables 5, 6, and 7). The existence of several different life history categories in each age group is sufficient reason to expect such variation.

Growth of each age group for spawning fish from the three streams is plotted in terms of mean length and weight in Figure 13. Since it is likely that only the largest fish in the youngest age groups were entering the spawning populations, the data may tend to overestimate growth of II+ and III+ fish. For age group III, the youngest adequately represented in all streams, overestimation is not considered serious enough to restrict usefulness of the growth data. Mean lengths for this age differed by less than 0.4 inch between streams. By age IV, the average growth pattern characteristic of each population had begun to take shape. Fish of the same age, after III+, were longest at Catherine Creek, shortest at Grout Brook, and intermediate at Cold Brook. Means were significantly different between spawning fish in each stream for age groups IV through VII.

Leveling of growth in older age groups was striking for Grout Brook. Fish in age group VI averaged 20.5 inches in length, while those in VII averaged 21.2 inches. Reduction in growth for Grout Brook reflects the lack of suitable forage fish in Skaneateles Lake; substantial populations of alewives in Seneca and Keuka Lakes promoted better growth among large rainbow trout.

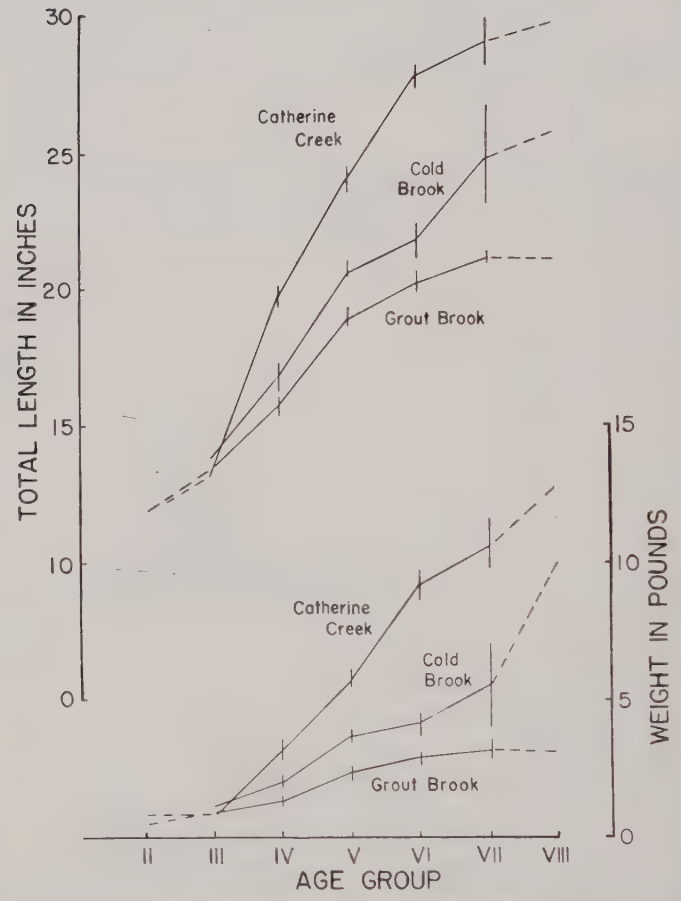

Figure 13. Growth rates as indicated by the average size of age groups in the spawning populations in three Finger Lakes tributaries, 1953–1956; annual samples combined. Vertical lines denote the 95 per cent confidence intervals for the individual means.

As expected, the same growth differences between spawning fish from each stream are shown by mean weights of the age groups. Spawning females, partly or fully spent, were arbitrarily excluded from weight analyses.

Several factors must be considered to properly interpret growth for any one stream. These include growth differences between the sexes, the effect of early parr growth, and annual differences in growth.

Growth Differences Between Sexes Length differences between the sexes, age groups III through VI, were tested for significance by the "*t*" test (Snedecor, 1946). Females were significantly larger than males through age group IV for Grout Brook and Cold Brook (Figure 14), and through age group V for Catherine Creek. By age VI, however, they appeared smaller (not significantly) than the limited number of males represented in this age group.

Shapovalov and Taft (1954) found female steelhead trout larger than males in age groups II and III. By age IV females were larger than males in one life history category (3 1), but in another dominant category (2 2) males were larger. In older age groups, either females or males were larger depending on the life history category.

Because males were numerically dominant in the younger age groups, the general growth curves previously described approximate those for the males. As females appeared in age group IV, and became numerically dominant in older age groups, the general growth curves shift to approximate those for the females.

Effect of Parr Growth Growth for the most important life history categories for each stream was analyzed to determine the influence of parr growth on the size attained by adult fish in the spawning populations. Annual samples were combined because some categories were poorly represented in different years. Growth differences between 15 pairs of categories were tested by the "*t*" test. Each pair contrasted fish of the same age, sex, and spawning history but with different numbers of years of parr life (e.g., 1/2 *vs* 2/1, and 1/2.2S *vs* 2/1.2S).

In 14 of the 15 pairs tested, adult fish with two years of parr life averaged shorter than adult fish with one year of parr life (Table 17). Differences in 9 of these 14 tests proved statistically significant at the 1 per cent level. Differences were sometimes 2 or 3 inches.

Real differences in annual growth must be distinguished from apparent differences caused simply by changes in the ratios of the life history categories. Thus it appears necessary that annual changes in growth for each stream be evaluated at the level of life history categories.

Annual Growth Differences Annual mean lengths for dominant life history categories for each stream are given in Table 18. Mean lengths were tested by analysis of variance to detect significant differences between years. Five of the nine categories showed statis-

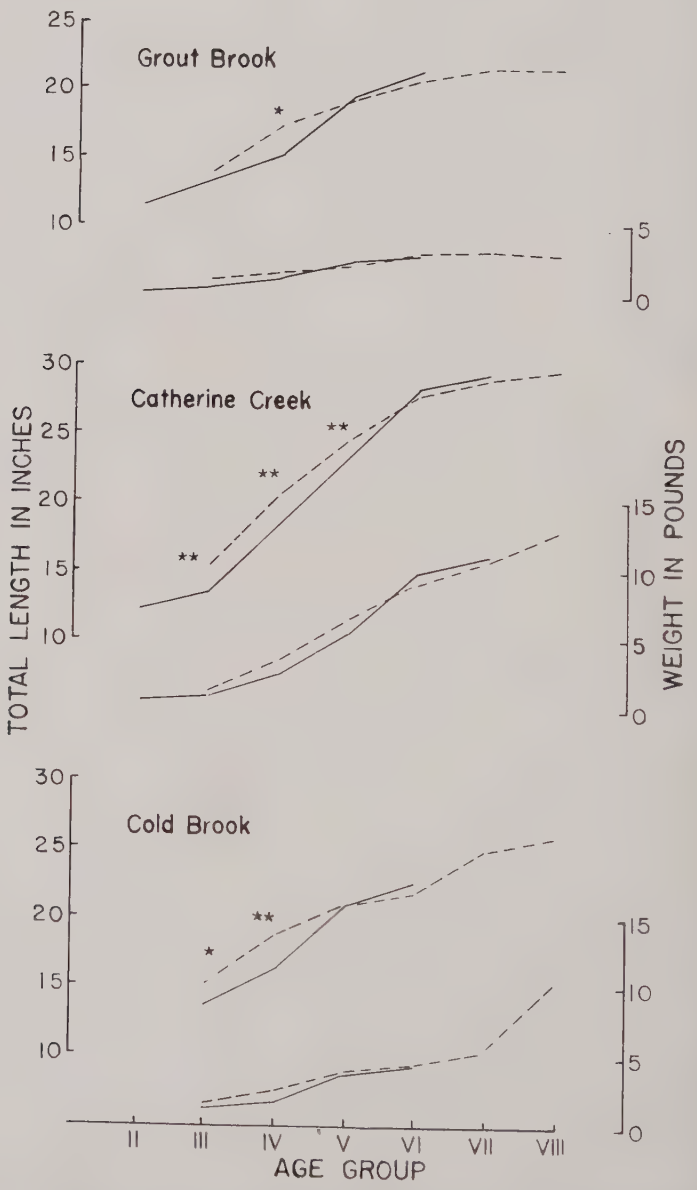

Figure 14. Growth rates of males (solid lines) and females (broken lines) as indicated by the average size of age groups in the spawning populations of three Finger Lakes tributaries, 1953–1956; annual samples combined. Significant differences in length, at the 5 per cent (*) and 1 per cent (**) levels, are indicated for age groups III to VI.

Table 17. Comparison Between Mean Lengths, of Fish of Similar Life History Categories But Differing in the Number of Parr Years, for Rainbow Trout in the Spawning Populations in Three Finger Lakes Tributaries, 1953–1956; Annual Samples Combined

Sex	Life history category	Sample size	Mean length	Standard deviation	Value of *t*
Grout Brook					
Male	1/2	26	13.3	1.06	2.22*
	2/1	68	13.7	0.84	
Male	1/3	15	17.8	1.31	6.18**
	2/2	94	14.7	1.98	
Female	1/3	31	18.1	1.05	4.44**
	2/2	30	16.5	1.82	
Male	1/2.2S	9	20.2	1.77	1.28
	2/1.2S	7	19.2	1.30	
Female	1/2.2S	5	19.7	0.48	0.65
	2/1.2S	18	19.3	1.32	
Catherine Creek					
Male	1/3	92	19.8	2.50	9.41**
	2/2	41	15.8	1.46	
Female	1/3	441	20.6	2.02	5.46**
	2/2	14	17.6	2.29	
Male	1/4	19	24.6	1.38	1.42
	2/3	9	23.6	2.12	
Female	1/4	67	24.3	2.24	3.89**
	2/3	57	23.0	1.71	
Male	1/2.2S	55	23.3	2.20	0.51
	2/1.2S	9	22.9	2.82	
Female	1/2.2S	133	25.3	2.17	3.56**
	2/1.2S	9	22.6	2.77	
Cold Brook					
Male	1/3	9	18.2	2.96	5.37**
	2/2	56	15.3	1.15	
Female	1/3	38	19.6	1.82	7.56**
	2/2	15	15.9	0.83	
Female	1/4	18	21.0	1.94	0.11
	2/3	73	20.9	1.59	
Female	1/2.2S	9	23.5	2.61	4.22**
	2/1.2S	17	20.4	1.77	

* Significantly different at the 5 per cent level.
** Significantly different at the 1 per cent level.

Table 18. Comparison Between the Annual Mean Lengths for the Dominant Life History Categories in the Spawning Populations in Three Finger Lakes Tributaries, 1953–1956 §

Life history category	1953	1954	1955	1956	Value of F
Grout Brook					
2/1 (male).....	14.8 (8)	13.7 (28)	13.4 (26)	14.0 (6)	4.10*
2/3 (female).....	18.8 (9)	17.9 (15)	19.2 (34)	19.1 (50)	1.75
Catherine Creek					
1/2 (male).....	13.1 (70)	13.8 (41)	13.4 (143)	14.2 (41)	7.35**
2/2 (male).....	15.8 (8)	15.4 (15)	16.1 (11)	16.3 (7)	0.83
1/3 (female).....	21.3 (47)	20.7 (170)	21.7 (62)	20.0 (162)	14.29**
1/2.2S (female).....	25.1 (6)	25.5 (46)	24.9 (63)	26.5 (18)	2.93*
Cold Brook					
2/2 (male).....	15.7 (5)	16.1 (13)	15.0 (38)	....	5.78**
1/3 (female).....	19.2 (15)	19.5 (9)	20.0 (14)	....	0.62
2/3 (female).....	20.6 (19)	21.4 (17)	20.8 (37)	....	0.91

§ Sample sizes given in parentheses.
* Significantly different at the 5 per cent level.
** Significantly different at the 1 per cent level.

tically significant growth differences between years at either the 5 or 1 per cent levels. Despite such differences, no distinct pattern emerges from the data to suggest consistent trends toward better or poorer growth for any stream over the study period. The spread between the most divergent means was 1.7 inches.

Growth for Grout Brook in 1939 A long-term comparison for Grout Brook can be made from scale samples, and length and sex

data, available from the 1939 spawning population (Rayner, unpublished).

Mean lengths for 13 life history categories represented in 1939 are compared with those for the same categories in the samples taken from 1953 to 1956 (Table 19). The four categories best represented

Table 19. Mean Lengths of Rainbow Trout in the Spawning Populations in Grout Brook in 1939 and 1953–1956*

Life history category	Sex	Mean length				Standard deviation	
		1939		1953–1956		1939	1953–1956
1/2	Male	13.4	(3)	13.2	(26)	....	....
1/2	Female	13.2	(2)	14.2	(3)	....	....
2/1	Male	14.1	(5)	13.7	(68)	0.87	0.71
2/1	Female	15.7	(4)	13.8	(3)	....	....
2/2	Male	16.6	(3)	14.7	(93)	....	....
2/2	Female	17.2	(19)	16.5	(30)	1.70	1.82
2/3	Female	19.3	(9)	18.9	(108)	1.81	2.01
1 2.2S	Female	20.7	(4)	19.7	(5)	....	....
2/1.2S	Male	19.4	(2)	19.2	(7)	....	....
2/1.2S	Female	20.5	(7)	19.4	(18)	1.53	1.32
2 2.2S	Female	21.8	(2)	20.5	(26)	....	....
1/2.3S	Female	21.9	(2)	21.1	(4)	....	....
2/1.3S	Female	21.0	(1)	20.6	(3)	....	....

* Sample sizes are given in parentheses.

in 1939 were tested ("*t*" test) for significant differences in growth, but none was evident. Nevertheless, these four categories and all but one of the others showed greater mean lengths in 1939, suggesting a reduction in growth since then.

Maximum growth, however, was not greater in 1939. The longest fish recorded then was 22.5 inches, compared with 24.3 inches in the recent samples. Severe leveling of growth among old fish, as noted in the present study, also took place in 1939.

Lamprey Parasitism

Parasite attacks by lake lampreys on rainbow trout in Seneca Lake were recorded as scars and wounds. A summary of these data is given in Table 20. Over the study period, 28 per cent of the fish were scarred and about 13 per cent bore open wounds.

Wigley (1953) found that the percentage of lake trout from Cayuga Lake possessing lamprey wounds increased with fish size. The mean number of wounds and scars per fish also increased with fish size.

Table 20. Lamprey Parasitism of Rainbow Trout from the Spawning Populations in Catherine Creek, 1953–1956

Year	Sex	Total fish examined	Scarred*		Wounded	
			Number	Per cent	Number	Per cent
1953	Male	144	..	..	15	10.4
	Female	96	..	..	17	17.7
	Combined	240	..	..	32	13.3
1954	Male	190	44	23.2	11	5.8
	Female	315	72	22.9	43	13.7
	Combined	505	116	23.0	54	10.7
1955	Male	265	39	14.7	13	4.9
	Female	234	73	31.2	40	17.1
	Combined	499	112	22.5	53	10.6
1956	Male	153	84	54.8	17	11.1
	Female	249	154	61.8	49	19.7
	Combined	402	238	59.1	66	16.4
Total	Male	752	167	22.2	56	7.4
	Female	894	299	33.4	149	16.7
	Combined	1,646	466	28.3	205	12.5

* Scars were not recorded in 1953.

Wigley concluded that two factors were responsible: (1) parasite preference for large trout; (2) high mortality among small lake trout attacked by lampreys.

Rainbow trout data for Seneca Lake reveal a similar relationship between parasitism and fish size. Fish less than 16 inches long were only slightly parsitized (Figure 15) while larger fish were relatively heavily parasitized. The fact that males averaged younger and substantially shorter than females in the spawning populations, probably accounts for the differences in frequency of parasitism between the sexes apparent in Table 20.

The proportion of wounded fish remained consistently low during the 4 year period, never exceeding 20 per cent (Table 20). Years 1953 and 1956 were high. Data on scarring are limited to three years, with percentages high in 1956 and low in 1954 and 1955. Although annual fluctuations occurred, parasite pressure seems to have remained at a fairly steady level throughout the four years. Substantial survival from lamprey parasitism is shown not only by the large numbers of scarred fish in every spawning population, but also by the fact that many surviving fish bore scars of from two to five attacks.

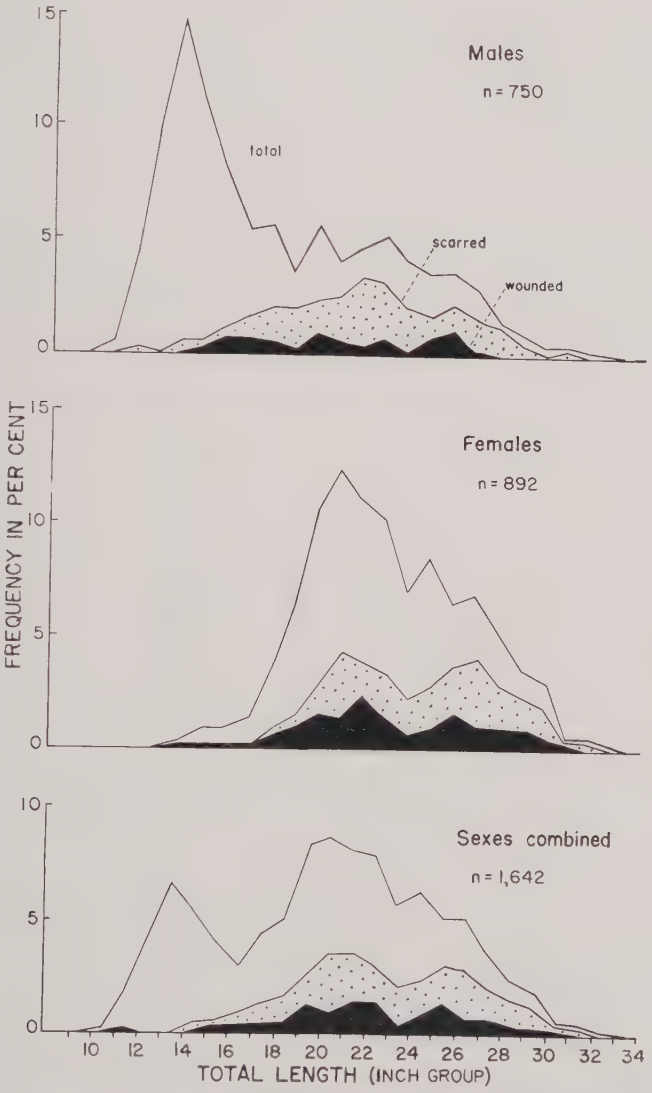

Figure 15. Length-frequency distributions of fish scarred or wounded by lamprey parasitism superimposed on that for total sample, for males, females and sexes combined, in spawning populations in Catherine Creek, 1954–1956; annual samples combined.

Fall Run Rainbow Trout

Fall runs of rainbow trout into Grout Brook, Catherine Creek,

and Cold Brook have been observed for some years. Of the 82 fish examined, in November and December since 1952, only two females had apparently spawned and only three others were ripe. Data on life history patterns, growth, age at maturity, etc., suggest that most fall-run fish probably comprise part of the spring spawning populations.

VITAL STATISTICS OF THE SPAWNING POPULATIONS

Knowledge of present exploitation of the spawning populations and the efficiency of the fishery is useful for evaluating management. Estimates of catch and related statistics of the spring rainbow trout fishery in Grout Brook, Catherine Creek, Cold Brook, and Naples Creek have been summarized elsewhere (Hartman, 1958). Exploitation, as well as mortality rates, is further discussed here.

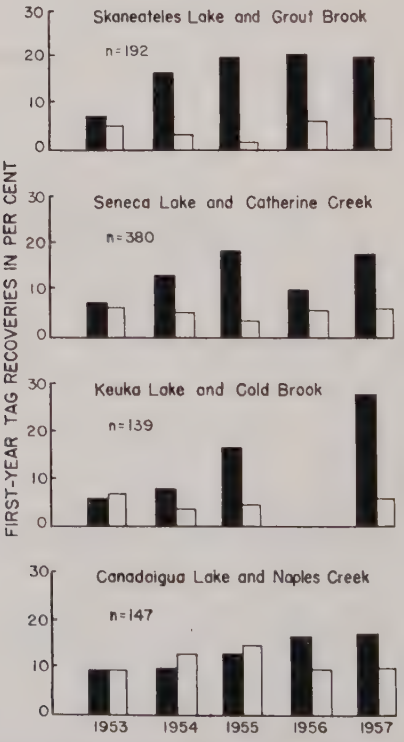

Figure 16. First-year stream (solid bars) and lake (open bars) exploitation of the spawning populations from four Finger Lakes tributaries, 1953–1957.

Exploitation

Exploitation of the spawning populations by both stream and lake fisheries can be estimated from tag recoveries. Such estimates are minimal because they depend largely on voluntary reporting by fishermen.

Stream *vs* Lake Recoveries First-year recoveries of tagged trout by the stream and lake fisheries were adequate in most cases for assessing their relative exploitation of the resource (except for those from Cold Brook in 1956). Recoveries have been transposed into percentages to facilitate comparison (Figure 16).

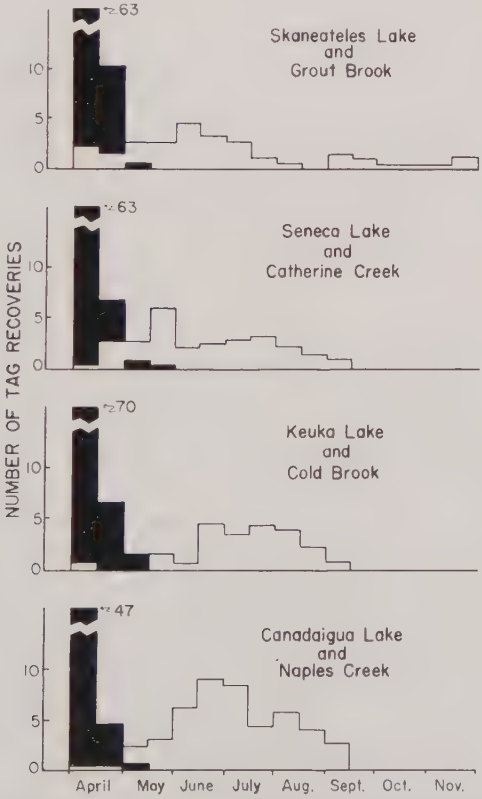

Figure 17. Seasonal recovery by stream (solid bars) and lake (open bars) fisheries of rainbow trout tagged in the spawning populations in four Finger Lakes tributaries, 1953–1957; annual recoveries combined. Recoveries during the extended open season at Skaneateles Lake in 1956 and 1957 included.

For three streams the spawning populations were much more heavily exploited by the stream fishery. Averages over the 5-year period were 17 per cent for Grout Brook, 13 per cent for Catherine Creek, and 15 per cent for Cold Brook.

Exploitation of these populations after they returned to the lakes, however, averaged only 5 per cent for each of the three streams. One or a combination of factors may have accounted for this reduction: (1) spawning populations were greatly reduced by the stream fishery; (2) salmonids generally suffer increased natural mortality following spawning; (3) the lake fishery exploited widely dispersed rainbow trout populations.

Although average stream exploitation for Naples Creek was similar (14 per cent), lake exploitation was substantially higher (12 per cent). As yet there is no satisfactory explanation for this. After April, tag recoveries from Canandaigua Lake and the other lakes were scattered throughout the fishing season (Figure 17).

Annual fluctuations in stream exploitation may have been partly due to differences in population size. However, it is felt that calendar shifts in the spawning seasons, and extremely varying fishing conditions, could easily account for such fluctuations.

A trend toward greater stream exploitation seems to have developed over the 5-year period. This may be an "artifact" caused by introducing the creel census in 1955. A more complete record of tag recoveries since then may have resulted, compared with the years 1953 and 1954 when recoveries were reported entirely on a voluntary basis. However, the trend may have been partly real, since evidence exists that stream fishing pressure materially increased during the census years.

Lake exploitation at Skaneateles, Seneca, and Keuka Lakes ranged from 2 to 7 per cent. Annual fluctuations played a relatively minor role in affecting the combined catch of the stream and lake fisheries. But since both fisheries were equally important with respect to the spawning populations of Naples Creek, annual fluctuations could substantially affect the total catch there. However, annual lake exploitation was fairly steady at Canandaigua Lake, ranging between 10 and 15 per cent.

During the study the lake fishing season ended on September 10, except at Skaneateles Lake where it was extended through November 30 in 1956 and 1957. No fish tagged in 1956 was reported taken during the extended season that year; despite this, the total catch was

a 5-year high at 28 per cent. In 1957, seven fish tagged that year were reported recovered during the extended fishing season. This additional 3 per cent compares favorably with the regular season's take of 3 per cent in the lake but constitutes a relatively minor portion of the combined stream and lake catch (26 per cent). There was no evidence (from tag returns) that total exploitation was substantially increased by extending the lake fishing season through November 30 for Skaneateles Lake. Data are not conclusive on this point, however.

Total Tag Recovery Recoveries of tagged fish in the second season after tagging were relatively low (Table 21), and in subsequent years were negligible. Most were made in the first season.

The proportion of tag recoveries in the three years following tagging represented, approximately, the total utilization of each spawning population. Fish tagged in the years 1953 to 1955 were sampled over at least three fishing seasons, but those tagged in 1956 and 1957 were sampled over only two seasons and one season, respectively. Total utilization for the 1956 and 1957 spawning populations was estimated by adding the average second-year values (for the period 1953–1956) to the recoveries of fish tagged in 1957, and the corresponding average third-year values to the recoveries of those tagged in both 1956 and 1957

Total utilization ranged from 12 per cent for Cold Brook for the 1954 spawning population to 36 per cent for Naples Creek for that of 1957. It remained fairly uniform from year to year for Grout Brook (average about 29 per cent), for Catherine Creek (25 per cent), and for Naples Creek (32 per cent). Cold Brook differed in showing substantial year to year fluctuations (average about 23 per cent).

Annual rates of total exploitation were derived by averaging the percentage of tag recoveries the first year after tagging (Table 21). For the 5-year period they were 20 per cent for Catherine Creek and Cold Brook, 22 per cent for Grout Brook, and 26 per cent for Naples Creek.

Percentage length-frequency distributions of fish tagged, and of tagged fish taken by angling, are illustrated in Figure 18. Both were quite similar for each stream, and chi-square tests of the homogeneity of the paired distributions showed no significant differences. Fish of different sizes in the spawning populations were exploited in the same proportions that they were present.

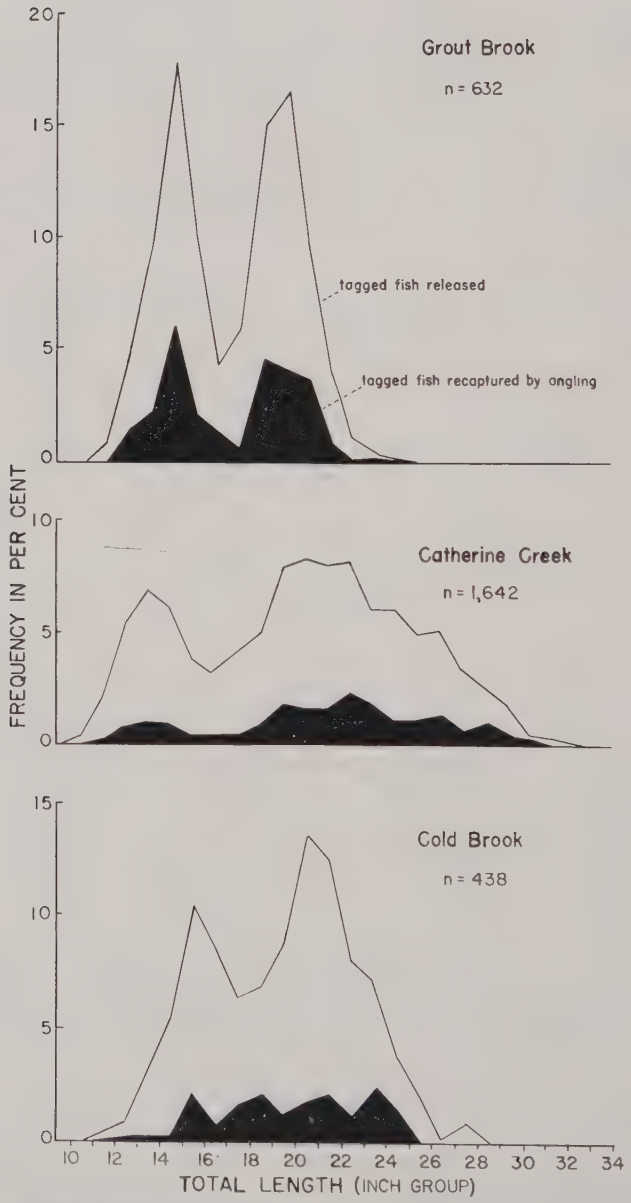

Figure 18. Length-frequency distributions of rainbow trout tagged in the spawning populations in three Finger Lakes tributaries and recaptured by angling, 1953–1956

Table 21. Successive Annual Angling Recoveries of Rinbow Trout Tagged in each Spawning Population in Four Finger Lakes Tributaries, 1953–1957, Expressed in Per Cent

Year of tagging	Tag recoveries: First year			Second year			Third year			Fourth year		
	M	F	Total *	M	F	Total	M	F	Total	M	F	Total
Grout Brook												
1953	9.7	14.8	12.9	3.2	7.4	5.9	6.5	..	2.4	..	..	..
1954	23.4	11.9	20.0	10.2	4.8	8.6	..	..	..	..	..	..
1955	25.3	19.4	22.3	2.1	8.2	5.2	1.2	..	0.5			
1956	26.4	30.3	28.0	3.8	6.1	4.8						
1957	39.1	20.0	26.1				(Period beyond term of study)					
Average	24.8	19.3	21.9	4.8	6.6	6.1	2.6	..	1.0	..	..	..
Catherine Creek												
1953	14.6	17.7	14.2	2.1	7.3	4.6	0.7	1.4	0.7	..	..	0.4
1954	18.9	17.7	18.4	1.6	3.9	3.0	..	1.6	1.0	..	0.3	0.2
1955	16.2	31.8	22.8	2.6	4.9	3.6	..	0.4	0.2			
1956	13.9	18.1	16.2	2.0	6.7	4.8						
1957	28.8	24.9	26.1									
Average	18.5	22.0	19.5	2.1	5.7	4.0	0.2	1.1	0.6	..	0.2	0.3
Naples Creek												
1953	19.2	19.4	19.4	....	8.3	4.8	..	5.6	3.2	..	..	..
1954	18.9	28.2	24.6	5.7	5.1	5.3	..	2.6	1.5	..	..	..
1955	25.7	33.3	28.8	2.9	4.2	3.4	..	4.2	1.7			
1956	25.7	25.9	28.0	..	..	..						
1957	28.3	32.7	30.7									
Average	23.6	27.9	26.3	2.2	4.4	3.4	..	4.1	2.1	..	..	..
Cold Brook												
1953	11.1	15.5	14.1	..	..	..	..	..	..	..	..	1.1
1954	9.6	12.5	11.0	..	..	..	2.0	..	1.0	..	..	..
1955	19.2	22.8	21.0	1.0	0.7	0.8	..	..	..			
1956	....	....	....	..	..	..						
1957	36.5	31.8	33.7									
Average	19.1	20.7	20.0									

* Includes fish of undetermined sex.

Differential Exploitation of the Sexes Comparative exploitation of males and females by the stream and lake fisheries during the first year after tagging is shown in Figure 19. Percentages are based on the number of each sex tagged, and are independent of the sex ratio.

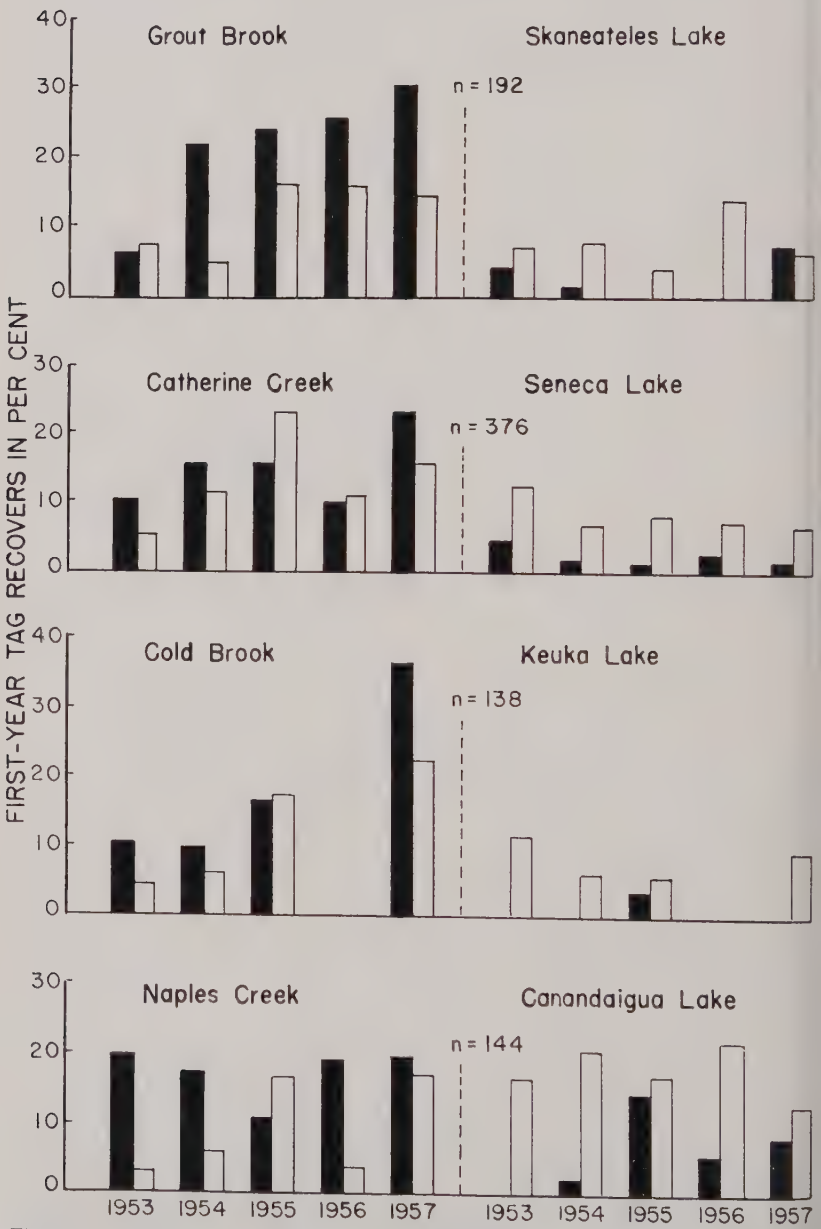

Figure 19. First-year stream and lake exploitation of males (solid bars) and females (open bars) from the spawning populations from four Finger Lakes tributaries, 1953-1957. Percentages based on total numbers of each sex tagged.

Males were more heavily exploited than females by the stream fishery in 14 of the 19 instances. Females were more heavily exploited by the lake fishery (18 of the 19 instances) as might be expected, since males were more severely reduced by the stream fishery and perhaps by natural mortality.

Although each fishery exploited one sex more heavily than did the other, total exploitation by both fisheries roughly balanced. Slightly more males were taken from the Grout Brook population and slightly more females from those of the other three streams (Table 21).

Rates of Mortality

In addition to exploitation by the fisheries, trout abundance is influenced by natural mortality.

Annual Survival Age-frequency distributions were unsatisfactory for estimating annual survival. Only the relative abundance of repeat spawners can be used (Ricker, 1948: 23). These were few in every spawning population. Considered on an age-frequency basis, they were completely inadequate for deriving reliable survival estimates by either Jackson's ratio method or from the slope of the log-frequency catch curve. Ricker noted the same limitations in reference to Atlantic salmon.

Two independent methods were used to estimate survival of the spawning populations: (1) the ratio of maiden fish and successive spawners in the spawning populations; (2) the ratio of tag recoveries in successive years.

It is assumed, in method (1), that the relative abundance of maiden fish and successive spawners in a sample from a spawning population reflects the survival rate between them, i.e., the average survival rate. The following formula was used:

$$s = \frac{S_2 + S_3 + S_4}{S_1 + S_2 + S_3}$$

in which,

s = average survival rate
S_1 = frequency of first spawners or maiden fish
S_2 = frequency of second spawners
S_3 = frequency of third spawners
S_4 = frequency of fourth spawners

Annual samples were combined for each stream to provide adequate sample sizes for repeat spawners. Pertinent statistics are given in Table 22. Information on maiden fish and repeat spawners for Naples Creek was not available.

Table 22. Numbers of Maiden Fish and Repeat Spawners in the Spawning Populations in Three Finger Lakes Tributaries, 1953–1956: Annual Samples Combined

Stream	Sex	First spawners	Second spawners	Third spawners	Fourth spawners
Grout Brook.....	Male	235	39	..	..
	Female	191	58	16	4
	Combined*	429	97	16	4
Catherine Creek..	Male	495	130	31	..
	Female	596	181	65	14
	Combined*	1,143	316	97	14
Cold Brook.....	Male	126	25	3	..
	Female	169	57	3	3
	Combined*	301	82	6	3

* Includes fish of undetermined sex.

In method (2) it is assumed that, for a particular group of tagged fish, the ratio of one year's recaptures to those of the preceding year reflects the survival rate. The formula used follows one proposed by Jackson (Ricker, 1948: 60):

$$s = \frac{R_2 + R_3 + \ldots + R_n}{R_1 + R_2 + \ldots + R_{n-1}}$$

in which,

R_1 = tag recaptures the first year after tagging
R_2 = the second year after tagging, etc.

Since spawning populations were tagged in five successive years, average values for R_1, R_2, R_3, and R_4 were computed. Actual numbers of recaptures could not be used because of two features of the data: (1) some groups of tagged fish were not sampled over four years; (2) different numbers of fish were tagged each year. Yearly recoveries were therefore converted to percentages of the particular group of tagged fish, and the average values for R_1, R_2, R_3, and R_4 (Table 23) were used.

Insufficient recaptures following the first year after tagging precluded use of this method to estimate survival for Cold Brook spawning

Table 23. Annual Survival Rates for Spawning Populations of Four Finger Lakes Tributaries for the Period 1953–1957, Expressed in Per Cent

Basis	Sex	Stream			
		Grout Brook	Catherine Creek	Cold Brook	Naples Creek
Repeat spawners..	Male	16.6	25.8	18.5	....
	Female	29.4	30.9	27.5	....
	Combined *	21.6	27.4	23.4	....
Tag recoveries....	Male	25.0	11.2	....	9.3
	Female	34.2	24.3	....	26.3
	Combined	25.4	20.3	....	18.5
Average annual survival.....		23.5	23.9	23.4	18.5

* Includes fish of undetermined sex.

populations. For Grout Brook and Naples Creek, R_4 recaptures were so limited that only data for three years were used.

Annual survival rates estimated by both methods are given in Table 23. They were generally of the same magnitude for Grout Brook and Catherine Creek. As there is no objective means for choosing one method of estimation over the other, the best estimates are considered the average of those from both methods.

As previously noted, females predominated among repeat spawners to a greater degree than among maiden fish. It has been shown that total exploitation of the sexes was fairly similar, perhaps slightly greater for females. Survival rates of males were substantially lower for each stream. It follows, therefore, that males must have been subject to a substantially higher rate of natural mortality following spawning. This seems to be common among salmonids (e.g., steelhead trout, Shapovalov and Taft, 1954) where the oldest fish are usually females. The predominance of females among repeat spawners in rainbow trout spawning populations in the Finger Lakes region probably resulted from this differential natural mortality.

Mortality Rates Percentages of exploitation by fishing (as previously derived) may be subtracted from the annual total mortality to obtain the percentage of loss from natural causes. However, Ricker (1948) and Eipper (1953) demonstrated that these components are not valid values for the actual *rates* of annual fishing loss or natural mortality when both are operating concurrently, "since some of the

Table 24. Determinations of Mortality Components for the Spawning Populations in Four Finger Lakes Tributaries, 1953–1957

Statistic*	Grout Brook	Catherine Creek	Cold Brook	Naples Creek
Survival rate (s)	0.235	0.239	0.234	0.185
Annual rate of total mortality (a)	0.765	0.761	0.766	0.815
Annual expectation of death from fishing (u)	0.219	0.195	0.200	0.263
Annual expectation of death from natural causes (v)	0.546	0.566	0.566	0.552
Instantaneous rate of total mortality (i)	1.450	1.430	1.460	1.690
Instantaneous rate of fishing mortality (p)	0.420	0.370	0.380	0.550
Instantaneous rate of natural mortality (q)	1.030	1.060	1.080	1.140
Annual rate of fishing mortality (m)	0.343	0.309	0.316	0.423
Annual rate of natural mortality (n)	0.643	0.654	0.660	0.680

* Symbols in parentheses are those used by Ricker (1948).

fish which are caught would have died from natural causes within the year and vice versa" (Carlander, 1958). It, therefore, was necessary to use instantaneous rates to derive valid values for these rates where each denotes "the fraction of fish present at the start of a year which would die during that year from the given cause, *if* no other cause of death existed" (Ricker, 1948). The results are given in Table 24.

MANAGEMENT IMPLICATIONS

These data indicate that the annual natural mortality among adult rainbow trout in the Finger Lakes region is consistently high and about double that for fishing. It follows that spawning populations should be utilized to a greater degree following spawning.

Assessment of Present Regulations

At present, the season for both lake and stream fishing opens April 1. In most years, spawning populations have run into the streams by this date, yet it is usually sufficiently close to the spawning season to permit some utilization of these fish by angling before they return to the lakes.

The bag limit of five for stream fishing does not restrict the catch during the opening week when angling is intensive. Creel-census data showed most of the successful fishermen caught only one fish. Very few caught more than two.

Consistently low exploitation in the lakes (except for Canandaigua

Lake), spread over the entire season, strongly suggests the bag limit of three for lake fishing does not seriously restrict the catch.

The size limit of 7 inches for stream fishing affords almost complete protection for 1- and 2-year parr, important constituents of future Grout Brook and Cold Brook spawning populations. The entire spawning populations of all streams exceed this size and are completely vulnerable to angling.

About half the males spawning for the first time are shorter than the size limit of 15 inches for lake fishing (Table 25), and have not yet been legally vulnerable to fishing. Many of the remaining males barely exceed 15 inches and probably were not vulnerable during most of the previous season. Most maiden females exceed 15 inches by a substantial amount. Undoubtedly many were legally vulnerable to lake fishing for one year before spawning for the first time.

Any increase in the size limit for lakes would protect more females until they spawned once, but would also protect more maiden males

Table 25. Length-Frequency Distributions of Maiden Males and Females in the Spawning Populations in Three Finger Lakes Tributaries, 1953–1956; Annual Samples Combined *

Inch group	Grout Brook		Catherine Creek		Cold Brook	
	Males	Females	Males	Females	Males	Females
10	..	..	5	..	..	..
11	5	..	30	..	2	..
12	25	2	78	..	4	..
13	45	2	108	2	15	..
14	87	12	85	6	18	3
15	29	9	40	8	28	10
16	12	5	25	11	18	10
17	4	21	22	30	3	15
18	10	64	8	55	6	14
19	11	56	24	82	3	23
20	5	16	13	92	9	35
21	2	3	11	91	5	28
22	..	1	13	78	5	15
23	..	..	10	51	3	15
24	..	..	9	40	4	..
25	..	..	6	26	3	..
26	..	..	4	15	..	..
27	..	..	2	2	..	..
28	..	..	..	2	..	..
29	..	..	..	2	..	..
30	..	..	1	1	..	..
Total	235	191	494	594	126	168

* The lake size limit of 15 inches is indicated.

from lake fishing following spawning. However, there is no justification at present for additional protection, and relatively low exploitation by lake fishing would seem to make this academic under present conditions.

Additional Exploitation

Exploitation of adult rainbow trout by lake fishing is spread fairly evenly throughout the entire season (April 1 to September 10 during this study). A trial extension of the lake season to December 1 was conducted at Skaneateles Lake in 1956 and 1957. The results showed little additional harvest. Exploitation in the lakes at any time of year is quite low (except at Canandaigua Lake) and large increases in the take are not expected to result from fall fishing, although it might increase as fishermen gain experience in angling for rainbow trout in the fall and as fishing pressure rises.

It has been shown that the spawning populations are subjected to much heavier natural mortality than fishing mortality after spawning. This clearly suggests that increased utilization of the fish after they spawn would be desirable. Since the bag limit does not restrict the catch now, raising it would not increase the catch. The present size limit does not protect any portion of the spawning populations from high exploitation in the streams. Further, although the April 1 opening date is arbitrary, it seems unwise to permit greater exploitation while the trout are on the spawning grounds. No information is available yet on the amount of natural spawning necessary to perpetuate the populations. Extension of the season into the fall months seems the only practical means at present to foster increased utilization of these populations. It should be mentioned that rainbow trout are in prime condition at that time of year.

It should be emphasized that these data and conclusions do not apply to the large juvenile populations in the lakes. Although specific information on juvenile rainbow trout is lacking, general reports suggest that they are not heavily exploited by the lake fishery. Permitting increased lake exploitation for the spawning populations would probably not lead to unusually large increases in the take of juvenile fish over 15 inches long.' But results of any such management program would have to be evaluated with both segments of the population in mind.

Spawning Tributaries

Maintenance and improvement of the major spawning tributaries

have been considered fundamental to management of the rainbow trout populations of the Finger Lakes region for some time. This investigation has brought out three cogent reasons that strongly support this earlier concept. All the streams studied are important natural hatcheries and produce large numbers of fry each year. The value of Grout Brook and Cold Brook as parr nurseries is evidenced both by stream inventories and by the early life history of most fish in the spawning populations. Finally, stream concentrations of spawning fish provide a better opportunity for utilization (except in Naples Creek) than occurs in the lakes.

The best information on spawning conditions at each stream has been given by Hatch (1956). In each case he found the first-class spawning area to be limited to about 18 per cent of the stream's length; this is almost completely used each year. Catherine Creek and Cold Brook had large amounts of second-class spawning area that lacked pools and shelter. Management to increase spawning facilities in these two streams should include providing pools and shelter in second-class spawning areas. At the same time, first-class areas should not be allowed to deteriorate. The limited amount of second-class spawning area at Grout Brook makes it even more imperative to maintain and improve first-class areas at that stream. However, the effects of any increase in parr production on the already relatively poor growth in Skaneateles Lake should be considered.

Figure 20. Unstabilized banks and lack of cover along Grout Brook near Skaneateles Lake in June 1957.

Figure 21. Stream conditions on Catherine Creek in June 1957: (above) long, shallow riffles with no cover, above Millport; (below) results of bulldozer activities.

Present conditions in all three streams are poor, and observations since 1953 have shown them to be rapidly deteriorating. The situation is least serious on Grout Brook where private landowners on their own initiative have constructed a number of small dams in the

Figure 22. Partial barrier to spawning migrations on Cold Brook near Pleasant Valley (June 1957).

middle section. Some of the more unfavorable conditions present to some extent on all three streams are illustrated in Figures 20, 21, and 22.

Stream maintenance and improvement, including removal or modification of existing barriers that impede spawning runs, should result in more complete utilization of upstream spawning areas. Such management might also increase the harvest of adult fish with no change in existing regulations. More pools and cover would spread both the fish and the heavy fishing pressure of opening week more evenly along each stream, increasing individual fishing efficiency and probably the catch. More cover might also hold spawned-out fish in the stream longer before they returned to the lakes, thus increasing the likelihood of their being taken.

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USE OF DRUGS IN HANDLING BLACK BEARS[1]

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ABSTRACT

Drugs were used to handle 383 wild black bears during a study to obtain data on movements, weight changes, tooth wear, longevity and reproduction. The principal method was live trapping and tagging.

Ether was found to be the most practical and effective drug for anesthetizing bears confined in culvert traps, and was used, by means of an "ether cone", to hold bears for weighing, measuring and tagging immediately following removal from such traps. When it was necessary to hold a bear in anesthesia for a longer period, etherization was followed by an injection of pentobarbital sodium. Succinylcholine chloride, a muscular relaxant, proved effective for immobilizing unrestrained bears so that they could be anesthetized with pentobarbital.

It often was necessary to give artificial respiration, and in some cases to administer a respiratory stimulant also, in order to revive anesthetized bears.

An investigation of the black bear (*Ursus americanus*) was begun in New York in 1956 to obtain information to guide management. Of particular interest were data on movements, weight changes, tooth wear, longevity and reproduction. The principal study technique was live trapping and tagging.

Erickson (1957), working on a similar project in Michigan, had successfully used ether to anesthetize bears caught in culvert traps, and had developed methods of physical restraint coupled with use of pentobarbital sodium to handle bears caught in steel traps. Both drugs were used during the study in New York, following procedures worked out by Erickson, with minor changes. Beginning in 1956, a relatively new muscular relaxant, succinylcholine chloride, was employed in handling both captive (zoo) and wild (steel-trapped) bears.

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In 1958, a carbon dioxide-powered gun firing dart syringes loaded with succinylcholine chloride was tried briefly. This technique and equipment were developed by Crockford *et al.* (1957) who used nicotine salicylate as the muscular relaxant.

GENERAL NOTES ON DRUG USE

Drugs were the key to safely and efficiently handling 383 wild black bears during the study (1956–1958). This figure represents 297 individuals, some of which were trapped or handled more than once. The numbers handled with various drugs or combinations of drugs are summarized in Table 1.

Table 1. Numbers of Wild Black Bears Successfully Handled with Various Drugs, Alone or in Combination

Drug	Number initial handlings	Number subsequent handlings	Total
Ether			
Alone	155	34	189
Followed by pentobarbital sodium	28	6	34
Pentobarbital sodium	99	27	126
Succinylcholine chloride			
Alone	1	8	9
Followed by pentobarbital sodium	10	11	21
Chloroform	4	..	4
Total	297	86	383

Ether was used to anesthetize 223 bears caught in culvert traps. Of these, 34 were held in anesthesia with pentobarbital sodium. The latter drug was used as a primary anesthetic on 126 bears caught in steel traps and restrained by choker and ropes, and as a secondary anesthetic on 21 bears that had first been immobilized with succinylcholine chloride. Nine bears were successfully handled with succinylcholine chloride alone. Chloroform was used to anesthetize four bears in 1956, but was abandoned because of its toxic effects.

In 1956 and 1957, 13 captive bears of known age obtained from zoos were handled by first immobilizing them with succinylcholine chloride and then anesthetizing them with pentobarbital sodium.

Routes of Administration

Oral administration is one of the safest and most common routes

used in veterinary practice. It is convenient and does not require that the drugs be sterile as is necessary for injection into tissue. But the disagreeable taste and odor of many drugs, especially anesthetics, cause rejection by most game animals. For this reason it was found impractical for black bears.

Of the several possible routes of parenteral administration, inhalation was used for ether, while intravenous, intrathoracic, intraperitoneal, and intramuscular injections (in that order according to rapidity of drug action) were considered for other drugs. Intravenous injection was ruled out as too difficult in physically restrained bears. Intraperitoneal injections were used for pentobarbital sodium in preference to intrathoracic because of the danger of introducing infection into the thoracic cavity and of irritating lung tissue. However, intrathoracic injection permits more rapid absoprtion from the pleural cavity. This route may be used for administering respiratory stimulants where speed of response is critical and intravenous injection is not possible. Intramuscular injection was the principal method used for succinylcholine chloride: other routes were impractical since bears on which this drug was used were either loose or incompletely restrained at the time.

Quantitative and qualitative response to a drug is influenced by its route of administration. Many drugs produce a given response with a smaller intravenous dose than those required for other routes. For example, oral administration of pentobarbital sodium required more than twice the parenteral dosage and also induced vomiting.

Factors Affecting Response

Practically nothing has been published on normal dosages of common drugs for game animals. Severinghaus (1950) described the use of Nembutal to anesthetize deer, and Hall *et al.* (1953) described the use of Flaxedil to produce paralysis in deer.

An example of inter-species variation is the relative response of white-tailed deer (*Odocoileus virginianus*) and black bear to succinylcholine chloride. Observations by Severinghaus and by Fay[2] indicate that ruminants may be more than five times as sensitive to this drug as non-ruminants. Jones (1954) emphasized that biological variation within a species makes the subject-response to a given dose of drug impossible to predict. Goodman and Gilman (1955) have also compiled useful and instructive information on this topic.

[2] L. D. Fay, Mich. Dept. Cons., personal communication, 1956.

Weight of the subject, more than any other factor, determines the quantity of a drug to be used. This is true for young animals as well as adults, but more care should be taken in administering drugs to young animals.

Variations in response may be associated with sex. However, no significant differences were noted for the drugs used on black bears.

The physiological state of an individual may alter response. For example, to achieve the same stage of anesthesia, an individual in a state of nervous excitement might require a larger dose than would a quiescent individual. Drug tolerance, or the failure of an animal to react to the ordinary dose of a drug, was not observed.

Instruments Used for Administering Drugs

Ether was sprayed into sealed culvert traps with a Smith, continuous-operation, 1-quart sprayer. The nozzle aperture was enlarged to permit more rapid spraying.

Hypodermic syringes were used to inject other drugs. Syringes are available with three types of tips, i.e., glass, metal, and Luer-Lok (a metal device into which the needle is screwed). For field use, the metal tips are more durable. The Luer-Lok tip has the advantage of securing the needle firmly. Metal syringes are available up to 50 cubic centimeters in capacity and because of their stronger construction are recommended for field use. For dosing bears, that may range from 15 to 600 pounds in weight, with different types of drugs, it is most efficient to have a series of syringes, including 5-, 10-, 20-, 30-, and 50-cubic centimeter sizes.

For intraperitoneal injections in black bears 16- or 18-gauge needles in 1½-, 2-, or 2½-inch lengths were most frequently used. Selection of needle length depends on the size and obesity of the bears involved. Needles of smaller gauge are useful for obtaining blood samples and for intravenous injections.

Characteristics of Anesthesia

The pattern of action of general anesthetics consists of a descending paralysis of the central nervous system that results in a progressive loss of consciousness. Loss of reflexes and of muscular activity is the principal advantage of anesthesia to the biologist since the problem of restraint is paramount in handling big game animals. Awareness of the pattern of action and ability to recognize the normal reflexes and their disappearance are important to the intelligent use of general anesthetics.

The action of general anesthetics is commonly divided into four somewhat arbitrary stages (Grollman, 1958; Jones, 1954; Wright, 1957): (1) imperfect or altered consciousness; (2) excitement; (3) complete unconsciousness or surgical anesthesia; (4) overdosage and medullary paralysis.

Stages (1) and (2) together constitute the induction period. The first lasts until consciousness is lost. Depth of anesthesia may be assessed by onset of inability to raise the head (Wright, 1957). Second-stage anesthesia is light; it may also be termed deep narcosis. Responses may be variable. Excitement as indicated by struggling is more pronounced under etherization than in response to pentobarbital. This stage marks the beginning of complete relaxation of the jaws and inability to move the tongue, but brisk pedal reflexes are present (Wright, 1957).

The third stage is divided into four planes which are differentiated chiefly by the character of the respiration, the movements of the eyes, and the size of the pupils. Muscles relax and reflexes disappear, one of the last to go being closure of the eyelids when the cornea is touched. Wright (1957) listed pedal reflexes as the best index for deeper planes of surgical anesthesia. Care must be taken in handling animals in deep surgical anesthesia since the tone of skeletal muscles completely disappears; animals are flaccid and prone to internal injury.

The fourth stage is paralytic; arrest of respiration and fall of blood pressure to the shock level are most characteristic of this dangerously deep anesthesia. All reflexes are lost, dilation of the iris is complete, and anal and urinary reflexes disappear. Supportive therapy may be successfully administered.

Table 2 is adapted from Grollman (1958). Neuromuscular reflexes are used as criteria for classifying the depth of anesthesia. Some responses not easily detected in the field have been omitted. No important departures from this pattern were noted for the black bear.

SPECIFIC DRUGS AND THEIR USE

The drugs which were used extensively in this study are described briefly together with the techniques used and results obtained. Recommendations are included that may be of value to persons using drugs to handle game animals. Two drugs, ether and pentobarbital sodium, were used for inducing general anesthesia. Chloroform was ruled out because of its toxic effect on the heart and liver. Succinylcholine chloride was used as a muscular relaxant to initially subdue bears that were caught in steel traps. In most cases the injection of this drug was followed by administration of a general anesthetic.

Table 2. Principal Characteristics of the Four Stages of General Anesthesia in the Dog

Plane	Respiration	Papillary size	Movement of eyeballs	Palpebral reflexes	Conjunctural reflexes	Pedal reflexes	Pulse rate	Tone of skeletal muscles
Stage I. Altered consciousness								
	Slow and deep; abdominal and thoracic	Moderately dilated	Voluntary	Present	Present	Present	Fast	Normal
Stage II. Excitement								
	Irregular in rate and depth; abdominal and thoracic	Widely dilated	Marked	Present	Present	Present	Fast	Normal
Stage III. Complete unconsciousness								
1. Light	Slow and regular	Slightly dilated	Marked	Present	Absent	Present	Normal	Normal
2. Moderate	Normal	Normal	Fixed	Present	Absent	Absent	Normal	Slightly diminished
3. Deep	Deep, abnormal	Dilated	Converge	Absent	Absent	Absent	Fast	Progressively diminished to completely flaccid
4. Dangerously deep	Shallow, abnormal	Widely dilated	Absent	Absent	Absent	Absent	Feeble	Absent
Stage IV. Paralysis								
	Paralyzed	Entirely dilated	Absent	Absent	Absent	Absent	Absent	Absent

Ether

This drug is potent; it produces anesthesia rapidly and permits equally rapid recovery. The margin of safety is wide and muscular relaxation is adequate. In fact, ether is the safest of all general anesthetics. Also, it is inexpensive. On the negative side, it is irritating to mucous membranes, its vapor forms an explosive mixture with air, and it is not completely stable in storage.

Within the tissues ether is stable and is eliminated in the same form in which it is inhaled. Ether dissolves in the blood stream and is transported throughout the body to fatty tissue into which it diffuses due to its greater solubility in lipoidal tissues. The central nervous system is more susceptible to the drug than other systems because of its high vascularity and lipoidal content. Consequently, when administration ceases, ether diffuses out of the brain more quickly than from other tissues. It is noteworthy that animals sacrificed soon after being etherized are not palatable because noticeable amounts of ether are retained in the tissue. Ether has a depressing effect that is due more to its concentration than to the quantity administered. Prolonging the induction of anesthesia exerts an unnecessary toxic effect and increases risk to the animal. Conversely, too rapid induction may paralyze the respiratory center and cause death.

Excretion of a volatile anesthetic involves the same diffusion processes as administration, but in reverse. About half of that present in the body is excreted within the first 30 to 60 minutes after the end of anesthesia (Jones, 1954).

Ether sprayed into a culvert trap in a concentration sufficient to anesthetize may be highly explosive. Open flame, sparks or other possible sources of ignition of an explosive mixture should be kept away from a culvert trap in which ether is being used, until it has been thoroughly aired. The bait rod should be removed from the trap before spraying ether, and the trap should be kept free of stones or other materials that might strike a spark.

Techniques Culvert traps were sealed before ether was introduced. Three traps were designed to permit bolting steel plates over the openings, but wet paper towels or wet cloth provided satisfactory seals. Masking tape was generally used in 1958. Commercial-grade ethyl ether was sprayed into a trap until the bear became quiet (Figure 1). Then, observations were made of the respiration rate and general condition of the animal (Figure 2), so that it could be removed from the trap promptly when satisfactory anesthesia was

Figure 1. Spraying ether into trailer-mounted culvert trap to anesthetize bear. Trap is sealed before spraying is begun.

reached. Pouring ether into a culvert trap was inefficient and extremely impractical, and is not recommended.

Results A total of 223 bears were anesthetized with ether during the three years of the study. Results were remarkably consistent because the etherizing procedure was basically the same in each case. The chief causes of variation were the size, age, condition and temperament of the bear, the time it was confined in the trap prior to anesthesia, and the air temperature and wind velocity. Five of these bears suffered respiratory failure. Artificial respiration and a respiratory stimulant were administered in each case. Three died and two recovered. In summarizing results (Table 3) observations that departed excessively from the average were omitted. Where handling techniques or malfunction of equipment were at fault, inclusion of the data would be misleading.

Discussion The most satisfactory technique required 0.9 to 2.0 (average 1.1) pounds of ether per bear. Ether was sprayed into a trap for an average of 9.1 minutes. Time to produce anesthesia ranged from 6.5 to 44 minutes (average 11.1). When a prolonged period was required to anesthetize a bear, the technique was often at fault or a physical difficulty arose, e.g., a sprayer nozzle being pulled off by the bear. Inadequate sealing of a trap, particularly if a wind

Figure 2. Listening to bear's respiration following second stage of anesthesia and just prior to removal from trap.

was blowing, prolonged the time needed to anesthetize. If a trap was opened too soon, before the animal was completely relaxed, it was necessary to continue spraying the anesthetic, increasing both the time to anesthetize and the amount of ether required. Two bears recovered very rapidly from ether anesthesia and escaped before handling was completed, emphasizing the need to watch anesthesia carefully. The traps averaged 8 feet long and 3 feet in diameter.

In preparing for anesthetization, a culvert trap should be moved immediately out of direct sunlight, the condition of the bear checked, and the trap sealed tightly in order not to prolong the period of induction. The bait rod should be removed as a precaution against igniting ether vapor.

Ether should be carried in tightly sealed cans and should be used as soon as possible after opening; otherwise peroxides form which irri-

Table 3. Summary of Use of Ether to Anesthetize Bears

Item	Average measurement	Numbers*
Amount of ether used	1.1 pounds	153
Administration in trap		
Onset of excitatory stage	5.6 minutes	201
Duration of excitatory stage	1.7 minutes	183
Termination of spraying	1.8 minutes	51
Interval before removal from trap	3.6 minutes	118
Total time to anesthetize	11.1 minutes §	156
Total time in anesthesia	27.0 minutes	119
Recovery time	2.7 minutes	33

* Number of instances in which measurement was recorded. Ether was used on 223 bears, but circumstances did not permit recording all items of data in each case.

§ Because of the variation in number of records involved, this figure is not an exact sum of the values for the preceding four items.

tate mucous membranes. Using 1.5 pounds to a 1-quart sprayer, the ether should be sprayed without interruption until the bear is quiet and beyond the excitatory stage. The nozzle of the sprayer should not be closer than 2 inches from the opening through which ether is being sprayed. Otherwise the bear may strike at it and pull it off. A block of wood between sprayer and trap will serve to maintain this space.

Spraying normally may be continued until about 1 pound of ether has been used, but stopped after about 7 minutes if the bear remains quiet. In some cases, bears may remain comparatively quiet throughout induction of anesthesia; thus it is important that spraying be stopped and the condition of the bear checked before anesthesia has progressed too far. Alertness must be maintained during etherizing. This is particularly important during the short interval between the spraying of ether and removal of the bear. Crew members must be ready to remove the bear from the trap quickly and apply artificial respiration (as described later) if breathing should stop. Normally a bear may be safely removed from a trap 2 to 4 minutes after the excitatory stage has passed. Respiration should be observed and visual checks made prior to removal. As a final test, the drop door of the trap can be raised about 6 inches and blocked in position, and the bear prodded with a blunt stick. If the bear shows no response, the door can be further raised and blocked to permit one to reach in and test the animal's resistance to extension of a hind leg. If its leg muscles can be easily extended, the bear may be removed. If the bear resists,

the door should be closed and additional ether introduced until satisfactory anesthesia is accomplished.

To maintain anesthesia, an 8-quart bucket containing a layer of cotton saturated with ether and held over the nose of a bear works very well. It may be necessary to drape the mouth of the pail with cloth, to maintain a heavy ether atmosphere around the bear's nose. The stage of anesthesia should be watched closely, maintaining the the animal in the upper planes of surgical anesthesia by repeated applications of the "ether cone". One person should be responsible for anesthesia while handling is underway.

When processing is completed, the bear should be removed from the trapping site. Unnecessary disturbance during the short recovery period should be avoided. If the bear does not recover promptly or is having difficulty in breathing, a respiratory stimulant may be administered to speed recovery, and artificial respiration applied.

Pentobarbital Sodium

Pentobarbital sodium is a general anesthetic that can be administered orally or by injection. It was first introduced in 1930 under the trade name Nembutal. It produces the same clinical stages of anesthesia as ether or chloroform, but is not so readily controlled. Whereas ether and chloroform are eliminated rapidly, non-volatile drugs continue to act until excreted or metabolized.

The principal effect of pentobarbital sodium and other barbiturates is to depress the central nervous system. It induces anesthesia with a minimum of excitement, and is rapid, particularly when given intravenously. Recovery may take hours, but is usually smooth and comparatively quiet. A wide margin of safety, between the anesthetic dose and minimum lethal dose, is a principal reason for its wide use. In domestic animals only 50 to 70 per cent of the minimum lethal dose is needed (Jones, 1954). Rate of administration influences the effect; too rapid injection results in a high local blood concentration which may paralyze the respiratory center. It is important to note that the concentration which inhibits the respiratory center is considerably less than that needed to arrest the heart. Thus, when respiration stops during barbiturate anesthesia, attention should be directed first to re-establishing respiration because the heart continues to function for a brief period (Jones, 1954).

There is no concentration of pentobarbital sodium in the central nervous system, although this is the principal site of action. Barbiturates readily diffuse through the placenta into the fetal circulation.

Dreisbach and Snyder (1943) showed that dosages of pentobarbita that failed to produce anesthesia in the female completely inhibite fetal respiration—a factor that may rule out use of this drug in handlin pregnant game animals.

Tolerance to pentobarbital and other barbiturates after repeate use has been shown by dogs and may be expected in bears that ar anesthetized frequently with the drug. A cross-tolerance to all bar biturates occurs after tolerance to one has developed. In dogs which have developed a tolerance to pentobarbital there is no change i minimum lethal dose (Jones, 1954).

In 1952 Svihla and Horita reported the use of Nembutal to anes thetize a black bear. Intraperitoneal injections at the rate of 25 milli grams per kilogram of body weight were administered to an adult mal restrained in a squeeze cage. Surgical anesthesia was attained withi 17 minutes and lasted for 83 minutes. Attempts at oral administratio were unsuccessful.

Erickson (1957) used 1 cubic centimeter of Halatal solution, con taining 65 milligrams of pentobarbital sodium per 5 pounds of body weight, on 13 male and 19 female bears. Sedation was produced i an average of 11 minutes. Recovery time for 15 bears averaged about 3 hours.

Stickley (1957) used pentobarbital sodium to repeatedly anes thetize three black bear cubs in order to X-ray their teeth. Dosage were at the rate of 10 milligrams per pound. Sedation resulted in ap proximately 10 minutes and extended for a period of 4 to 5 hours. Bear less than 5½ months old were anesthetized by oral administration of th drug on an empty stomach; after that, by intraperitoneal injection.

Techniques Attempts to anesthetize captive black bears b mixing powdered pentobarbital sodium into their food or by placin capsules of the drug into pieces of meat and bread were unsuccessful The drug's bitter taste was detected immediately. Bears either avoide the capsules or spit them out. Apples, honey and cookies containin this drug were completely rejected. The same foods, untreated, wer eaten readily. An attempt to administer pentobarbital sodium orall to one bear, which had been offered drugged foods earlier, was als unsuccessful.

Two bears consumed their normal daily ration into which pow dered pentobarbital sodium had been mixed. Response was slow One vomited within 1½ hours; the second consumed the partiall digested food of the other. This bear, having ingested more tha

twice the normal dose, showed some response in 3 hours, but after 4½ hours anesthesia was inadequate for handling.

Two bears which had been fasted for a day were fed their normal rations into which a heavy dose of pentobarbital sodium had been mixed. The bears picked at the food and slowly consumed all. Within 2½ hours both vomited most of it, but showed no other effects of the anesthetic. Later attempts to induce five other captive bears to eat horse meat into which pentobarbital sodium had been introduced were completely unsuccessful.

Pentobarbital sodium[3] was used in handling 181 wild bears and 13 captive (zoo) bears. Intraperitoneal injection was the principal means of administration (Figure 3). The most consistent success was achieved with injections into the peritoneal cavity on either side of the median line and behind the diaphragm. Most of these bears were anesthetized following capture in steel traps and physical restraint by trussing with ropes; 21 steel-trapped bears had first been immobilized with succinylcholine, and 34 that had been taken in culvert traps, with ether. When used alone, the dosages ranged from 7 to 20 milligrams per pound of body weight (Table 4). Captive bears handled with this drug were transferred without other restraint. Since they were to be autopsied, dosages were heavier than would have been used normally.

Considerable difficulty was experienced in 1957 with intraperitoneal injections, due to inexperience and faulty technique. Longer (2-inch) needles were required to permit introduction of the drug into the peritoneal cavity of extremely fat bears. Some ineffective injections may have been made into the intestine. Violent struggling by a physically restrained bear following capture in a steel trap may also make some injection failures unavoidable.

Results The doses administered to 160 wild bears for which data are complete are given in Table 4. Of these, 90 were male and 70 were female; 25 were cubs. The mean dose was 11.9 milligrams per pound of body weight. The average time required to produce third-stage anesthesia was 15 minutes. No significant differences were noted between sexes, or with respect to size or age, in the mean dosages per pound of body weight required to attain anesthesia.

[3] The solution generally used contained 65 milligrams of pentobarbital sodium per cubic centimeter. It was prepared at Cornell University according to the following formula: pentobarbital sodium (J. T. Baker Chemical Co.), 16.25 grams; 95 per cent ethyl alcohol, 30 milliliters; propylene glycol (1, 2-Propanediol of Eastman Kodak Co.), 50 milliliters; distilled water, 250 milliliters.

Table 4. Dosages Required to Anesthetize 160 Bears with Pentobarbital Sodium *

Dosage §	Body weight in pounds								Total
	0–49	50–99	100–149	150–199	200–249	250–299	300–349	350–399	
7.0– 7.9	2	3	..	..	..	..	..	..	5
8.0– 8.9	2	1	1	..	1	..	1	..	6
9.0– 9.9	2	1	4	5	2	2	..	..	16
10.0–10.9	4	5	10	5	3	2	..	..	29
11.0–11.9	2	3	6	5	5	1	3	1	26
12.0–12.9	1	1	11	1	4	2	3	..	23
13.0–13.9	5	2	12	1	2	1	1	2	26
14.0–14.9	..	4	5	1	..	..	..	..	10
15.0–15.9	..	..	2	2	..	1	..	..	5
16.0–16.9	..	1	..	..	..	..	1	..	2
17.0–17.9	..	1	1	..	..	..	..	..	2
18.0–18.9	..	1	2	..	..	..	..	..	3
19.0–19.9	..	2	3	..	..	..	..	..	5
Total	18	25	57	20	17	9	9	3	158

* One bear weighing 411 pounds was anesthetized with a dosage of 9.0-9. milligrams per pound; and one weighing 562 pounds, with 10.0-10.9 milligram per pound.

§ As milligrams per pound of body weight; concentration of pentobarbita sodium, 65 milligrams per cubic centimeter.

Thirteen had incurred serious injuries, i.e., fractures of fore or hin legs, dislocated or broken carpals or metacarpals, and one dislocate elbow. There was no indication that these injuries altered respons to the anesthetic.

Recovery times were not recorded for most bears handled wit pentobarbital. Many were also given booster shots (during recover period) and, while all were checked to ascertain that recovery wa complete, some bears were not checked until hours after expecte recovery. Recovery times noted ranged from 47 minutes for a lightl anesthetized cub to 10¼ hours for a 108-pound female A 109-poun male, given an over-dose (18.2 milligrams per pound of body weight) remained anesthetized for more than 8 hours, but when disturbed i roused and ran off.

Eight adult bears (five females and three males) were safely main tained in anesthesia for more than 12 hours. An example of extende anesthesia was provided by a 145-pound adult female that was initiall anesthetized in 10 minutes with 30 cubic centimeters of pentobarbita (13.4 milligrams per pound of body weight). Three hours and 2 minutes later this bear was capable of raising her head and the firs

Figure 3. Intraperitoneal injection of pentobarbital sodium. Injection is made into abdominal region to rear of diaphragm.

booster shot of 20 cubic centimeters was given. Partial recovery was evidenced in an additional 9 hours whereupon a second 20-cubic-centimeter booster was injected. This procedure was repeated at 4-, 5-, and 13-hour intervals—an elapsed time of more than 34 hours.

No mortalities resulted from normal handling with pentobarbital. Eleven bears were administered a respiratory stimulant (Am-pent) to speed recovery following handling.

DISCUSSION Intraperitoneal injection will usually be used to administer pentobarbital sodium under field conditions. Intravenous injection is not practical on most steel-trapped bears, due to struggling following restraint; nor for bears anesthetized with ether or immobilized with succinylcholine chloride, due to rapidity of action and absence of response.

In administering pentobarbital sodium it must be realized that no dosage formulae may be followed arbitrarily. Experience in the technique of drug injection and familiarity with responses and reflexes indicative of stages of general anesthesia are of paramount importance. Until experience is gained, the following cautious procedure of injection "to effect" which will guard against fatalities should be used: (1) estimate the weight of the animal; (2) calculate the dose and administer half this amount; (3) wait approximately 10 minutes to observe reactions; (4) proceed with remainder of the calculated dose or portion of it, based on disappearance of the animal's normal reflexes. A full dose, based on the rate of 12 milligrams per pound, may be administered safely in most cases. This is about 1 cubic centimeter, at a concentration of 65 milligrams per cubic centimeter, per 5½ pounds of body weight.

Weight is the most important factor upon which dosage is based. In large bears of 200 pounds and over, weight estimation becomes less accurate and bears of this size are frequently very fat. A safe procedure in such cases is to estimate the total weight, deduct the estimated weight of fat, and calculate the dose on the adjusted weight. For very fat bears, a dosage based on not more than 80 per cent of the estimated weight should provide a safety margin in most cases.

If a bear is in the sun, exhausted from fighting the trap, suffering from severe trap-inflicted injuries or shock, or does not appear normal, the initial dosage should be reduced and administered "to effect".

If no response is obtained from a full dose, a minimum of 20 minutes should be allowed for the drug to take effect before repeating dosage. One should keep in mind that, once a drug has been injected, it cannot be removed. If no response results from the initial injection, it may be assumed that it was faulty, i.e., the drug was injected into fat or the intestine and was ineffective. Another full dose, or a portion of it, may be given, based on the animal's response to the initial dose. If the animal was excited and struggling violently, the adrenalin in the blood, which counteracts the barbiturate, may take several minutes to wear off, and thus extend the time normally required for the drug to take effect.

Following normal anesthesia and as the animal begins to regain consciousness, additional doses of the anesthetic may be administered to effect to maintain a bear in anesthesia. If respiration ceases, artificial respiration should be given immediately and a respiratory stimulant administered.

Succinylcholine Chloride

Succinylcholine chloride, a muscular relaxant, was the most spectacular of the three principal drugs used. Its potential for capturing and handling big game animals has been barely explored. Muscular paralysis results from blockage of nervous transmission at the myoneural junction. (Curariform drugs are also blocking agents for neuromuscular transmission but act by different mechanisms.) Muscular paralysis is of short duration followed by extremely rapid recovery. Neuromuscular depression is preceded by transient stimulation. As paralysis proceeds the animal falls to its side and lies inert. Symptoms of the drug's action may include muscular tremor. The respiratory muscles are the last to be affected, but succinylcholine and other neuromuscular blocking agents may at times produce prolonged apnea.

Succinylcholine should be administered only by persons prepared to give supportive therapy. Succinylcholine chloride is shorter-acting than tubocurarine, a crystalline alkaloid isolated from curare, and is better suited for brief procedures (Grollman, 1958). The drug does not induce anesthesia nor analgesia. Its effect is not increased by use of ether or pentobarbital sodium for general anesthesia.

Succinylcholine chloride[4] was first used in this study in 1956 (Black, 1957). It provided an efficient solution to the problem of safely moving bears confined in zoos. A few cubic centimeters injected into muscle tissue would quickly immobilize a bear so that a general anesthetic could be administered safely that would last for several hours. In 1957, Anectine was used to immobilize initially a few wild bears caught in culvert traps, and in 1958 it was relied upon extensively to immobilize bears caught in steel traps. Also, two unrestrained wild bears were removed from trees by use of Anectine. Whenever prolonged immobilization was required a general anesthetic, such as pentobarbital sodium, was given.

Techniques A simple device, consisting of a 5- or 10-cubic-centimeter Ranch Record syringe mounted in a clamp device on a 12-foot take-down rod, was employed to administer the drug (Figure 4). Both inside surfaces of the wooden clamp were inletted to receive the handle of the syringe which was secured by a wing nut. The barrel and plunger were immobilized with a piece of scotch tape after the syringe was filled with the prescribed dosage. The syringe was then

[4] The commercial preparation used was "Anectine" produced by Burroughs-Wellcome and Co.

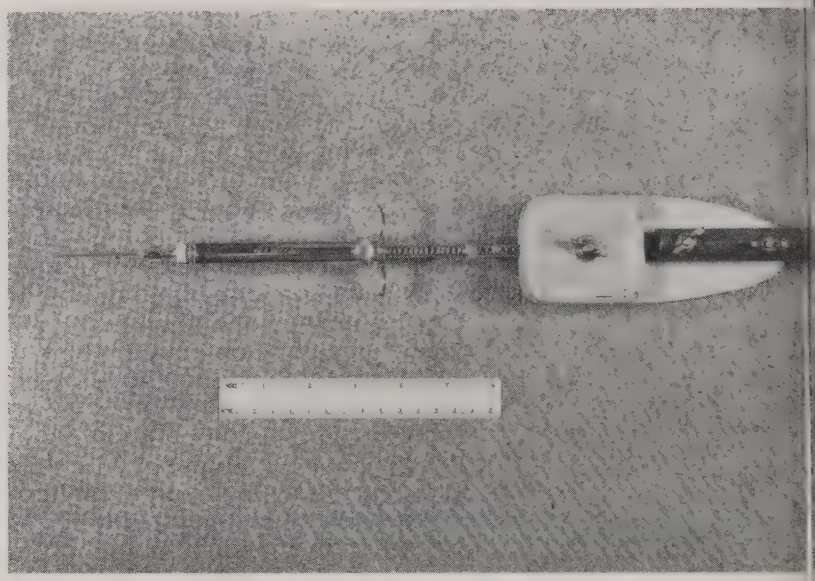

Figure 4. Clamp used to hold metal-barreled syringe on 12-foot pole for injecting succinylcholine chloride into unrestrained or steel-trapped bears.

fastened to the rod and the instrument was ready to use. It was brought close to the rear quarters of a bear and thrust forward with a light, quick thrust. Rapid closure of the syringe and successful injection were effected at the instant the 16- or 18-gauge, 1½-inch needle pierced the skin.

Anectine was successfully administered intramuscularly to bears in a solution containing 20 or 50 milligrams per cubic centimeter; the dosage rate varied from 0.1 to 0.4 milligram per pound of body weight. Dosages were determined empirically, but effects of the drug on dogs were used as a guide; 25 milligrams per 100 pounds of body weight were tentatively indicated.

Results Succinylcholine chloride was used successfully to immobilize 30 wild bears and 13 zoo bears. Notes on handling 24 wild and 11 captive bears are presented in Table 5. Injections given to 11 additional wild bears were apparently ineffective, possibly due to insufficient dosage or faulty injection.

Bears of both sexes, ranging in weight from 62 to 548 pounds and in age from yearlings to over 8½ years, were successfully handled. Average dosage was 0.23 milligram per pound administered at concentrations of either 20 or 50 milligrams per cubic centimeter. Mean

TABLE 5. NOTES ON HANDLING BEARS WITH SUCCINYLCHOLINE CHLORIDE*

Sex	Age §	Body weight in pounds	Dosage†	Time to immobilize	Effect following injection; remarks
			Captive bears		
Female	4 yr., 9 mo.	126	0.40	30–35 sec.	Ran 20–30 feet, stood a few seconds, then down
Female	4 yr., 9 mo.	157	0.32	30–35 sec.	Lost bladder control almost immediately, ran a few steps, then down
Male	4 yr., 9 mo.	236	0.21	45 sec.	Moved 15–20 feet, stood a few seconds, then down
Male	3 yr., 9 mo.	242	0.21	2 min., 25 sec.	Licked chops, gasped, moved a few feet, then down
Male	3 yr., 9 mo.	200 (est.)	0.25	3 min., 30 sec.	Bawled and muscles responded when prodded; second injection (not included in dosage) required to quiet fully
Male	4 yr., 10 mo.	391	0.19	2 min.	Bawled, lost control of anal sphincter, then down; initial injection not effective
Female	6 yr., 10 mo.	247	0.35	1 min., 30 sec.	Ran about, stood a few seconds, then down
Male	8 yr., 10 mo.	411	0.21	5 min.	Ran about, stood a few seconds, then down
Male	6 yr., 10 mo.	320	0.27	10 min.	Ran about, stood a few seconds, then down
Female	8 yr., 10 mo.	297	0.29	2 min.	Ran about, stood a few seconds, then down
Male	1 yr., 3 mo.	125 (est.)	0.24	1 min., 30 sec.	Ran about for 1 minute with progressive loss of muscular control, then down

Table 5. (*continued*)

Sex	Age §	Body weight in pounds	Dosage	Time to immobilize	Effect following injection; remarks
		Wild bears, handled while in culvert traps			
Male	5½–8½ yr.	281	0.21	45 sec.	
Male	2½–4½ yr.	180 (est.)	0.17	1 min.	
Male	5½–8½ yr.	350	0.25	6 min.	Drooped head after 3 minutes and could not stand after 5 minutes
Male	2½–4½ yr.	391	0.22	6 min.	Exhibited muscular tremors after 2 minutes
Female	2½–4½ yr.	176	0.28	3 min.	Gradually lost muscular control
Female	Yearling	88	0.14	1 min.	Gradually lost muscular control
Female	5½–8½ yr.	160	0.27	1 min.	Gradually lost muscular control
Male	2½–4½ yr.	246	0.35	1 min.	Could not stand after 30 seconds, but responded to prodding
Male	2½–4½ yr.	246	0.38	6 min.	Exhibited muscular tremors in front legs after 4 minutes; same bear as above
Female	2½–4½ yr.	204	0.36	3 min.	Down after 3 minutes but continued mild struggling
		Wild bears, unrestrained or handled while in steel traps			
Female	5½–8½ yr.	317	0.31	2 min.	Gradually lost muscular control; when injected was regaining consciousness from pentobarbital anesthesia

TABLE 5. (*continued*)

Sex	Age §	Body weight in pounds	Dosage	Time to immobilize	Effect following injection; remarks
Wild bears, urestrained or handled while in steel traps—*Continued*					
Male	Yearling	119	0.21	1 min., 15 sec.	Gradually lost muscular control
Male	Yearling	122	0.16	2 min.	Same bear as above
Male	5½–8½ yr.	312	0.22	6 min.	
Female	5½–8½ yr.	124	0.20	2 min., 10 sec.	Injection by dart syringe fired from a "Cap-Chur" gun
Female	Yearling	62	0.16	4 min.	Gradually lost muscular control; bear was in tree, completely unrestrained
Male	Yearling	72	0.14	2 min.	Gradually lost muscular control; bear was in tree, completely unrestrained
Male	2½–4½ yr.	102	0.20	2 min.	Stopped breathing 1 minute after immobilization; artificial respiration applied for 10 minutes before breathing resumed
Male	2½–4½ yr.	222	0.13	6 min.	
Male	2½–4½ yr.	133	0.15	3 min.	
Female	5½–8½ yr.	170	0.18	1 min.	
Female	2½–4½ yr.	105	0.10	2 min.	
Male	2½–4½ yr.	124	0.12	2 min.	
Male	2½–4½ yr.	113	0.18	1 min.	

* Most of these bears were safely anesthetized with pentobarbital sodium following immobilization with succinylcholine chloride.

§ Age of captive specimens based on accession records of the zoo where bear was held; age of wild specimens judged from tooth replacement and wear, weight and skeletal size.

† In milligrams per pound.

time to induce paralysis was 2.7 minutes. Differences noted between sexes in response to the drug are probably not meaningful.

No fatalities resulted among captive bears, but one wild bear died. This bear was given an initial full dose of succinylcholine chloride. Relaxation did not occur, possibly because of faulty injection. After waiting 10 minutes, which would be a minimum length of time for the effects of the initial dose to be dissipated, additional partial doses were given at 2- to 3-minute intervals. After the sixteenth partial dose was injected, the bear was prostrated and breathing had stopped. Artificial respiration and a respiratory stimulant (Am-pent) were administered in an unsuccessful effort to revive the animal. Such administration of partial doses is not recommended. Should an initial dose prove ineffective, a lapse of 30 minutes would be sufficient to eliminate its effects, after which a second full dose could be administered. Two other bears suffered respiratory difficulty. In one case, recovery was rapid without treatment; in the second case, breathing ceased 3 minutes after injection and 1 minute after the bear was immobilized. Artificial respiration was given immediately and continued for 10 minutes before normal breathing was resumed. No respiratory stimulants were administered.

Twenty-one of the bears effectively handled with succinylcholine were safely anesthetized with pentobarbital while paralyzed; thus recovery times (from the effects of succinylcholine) were not noted in most cases. One recovered in 11 minutes after initial injection of succinylcholine, before any effects of injection with pentobarbital were observed.

A 124-pound adult female trapped in a steel trap was given succinylcholine with a dart syringe fired from a "Cap-Chur" gun at less than 10 yards. The syringe entered the right hip and the needle may have penetrated the femur. Dosage was at the rate of 0.20 milligram per pound of body weight. The bear was not fat, but had incurred three broken toes. Complete relaxation resulted in 2 minutes and 10 seconds. The bear was safely given pentobarbital before complete recovery from succinylcholine. This was the only bear successfully handled by this method. A succinylcholine-loaded dart syringe, at a dosage rate of 0.20 milligram per pound of body weight, was shot into the rear quarter of a 181-pound adult male following its recovery from ether. Distance was approximately 10 yards. The bear was followed for 10 minutes, but no effects were noted. It was not possible to determine whether the syringe failed to function properly because it was not recovered. A similarly loaded dart syringe was shot into a third

Small adult bear immobilized by succinylcholine chloride injected by a dart syringe fired from a "Cap Chur" gun; note syringe in right flank.

bear, caught in a steel trap, but the syringe did not function due to its low velocity at impact.

Two yearling male bears (62 and 72 pounds) were successfully removed from trees by drug injections. The bears were wild and unrestrained. Intramuscular injections of succinylcholine, 0.15 milligram per pound of body weight, were given from adjacent trees by means of a syringe clamped to a 12-foot rod. Relaxation was achieved in 2 to 3 minutes and the bears slipped to the ground unhurt.

Discussion Weight is the most important criterion in dosage determination. The large muscle mass in the hind quarters is the preferred site for injection.

Success may be observed more promptly than with pentobarbital. If no response is observed within 10 minutes, injection was probably faulty or ineffective and a second partial dose may be given. If the initial dosage prostrated the animal but did not sufficiently immobilize it to permit handling, or if the animal is recovering from the effects of a normal dose, additional partial doses may be administered as required, depending on the animal's response and the ability of the operator to evaluate properly the effects of the initial dose.

Succinylcholine is not an anesthetic nor analgesic; therefore, an

animal immobilized with this drug is fully conscious and sensitive to pain. It must be treated accordingly.

TREATMENT FOR RESPIRATORY FAILURE

If respiration stops as a result of overdosage with a general anesthetic, artificial respiration must be applied immediately. This may be accomplished by laying the bear on its side, making sure the trachea is unobstructed and the tongue free, and applying pressure at regular intervals to the chest with one knee by rocking forward on the toes. A respiratory stimulant should also be administered as soon as possible. Artificial respiration is the only effective therapy following use of succinylcholine. Recognition that picrotoxin and other compounds employed to lessen the degree of anesthesia are harmful has placed emphasis on maintaining adequate artificial respiration.

Three principal stimulants of the central nervous system were considered. Pentamethylenetrazol is a relatively non-toxic stimulant of value for treating poisoning by depressants and for arousing an animal from anesthesia. The drug is rapidly detoxified and its action may be controlled well. Its relatively wide safety margin gives it an advantage over picrotoxin and amphetamine.

Picrotoxin is a powerful stimulant unequalled for its long-lasting effects. But it is also highly toxic. Its main therapeutic use has been to counteract barbiturate poisoning. Jones (1954) cited two reasons that now disqualify it: (1) it is too potent to use for barbiturate poisoning since it is apt to cause convulsive seizure; (2) the latent period which characterizes its clinical use is too long.

Amphetamine is also a potent stimulant of the central nervous system. It is capable of lessening the degree of depression produced by anesthetics and hypnotics, and it has the ability to stimulate the depressed respiratory center.

Am-pent[5] was kept available for emergency use in cases of respiratory difficulty and was occasionally used in 1957 and 1958 in conjunction with artificial respiration. Each cubic centimeter contained 1.5 grains (approximately 100 milligrams) of the drug, in an aqueous solution of 0.1 per cent sodium phosphate di-basic, preserved with 0.25 per cent phenol. Dosage was governed by the depth of existing depression and the size of the bear, but did not exceed 1 cubic centimeter per 25 pounds of body weight administered by intrathoracic injection. This drug was administered to bears suffering various

[5] Trade name of form of Pentamethylenetetrazol produced by Jensen Salsbery & Co.

degrees of respiratory difficulty. Artificial respiration was applied immediately when breathing stopped and Am-pent was administered secondarily, i.e., reliance for resuscitation was placed primarily upon maintaining respiration rather than upon stimulating the respiratory center. No dramatic responses to the drug were noted. In fact, it is difficult to assess its role in therapy for black bears.

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TROUT GROWTH IN HATCHERIES[1]

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ABSTRACT

Water temperature, species and feeding level are major factors that affect trout growth. Data for brook trout are analyzed to show that hatchery trout having adequate food will remain constant in body form for at least 1½ years and, at a particular temperature, will increase in length at a constant rate. Also, the cube root of the weight is proportional to the length. A table is included giving the relationship of weight to length for brook trout, brown trout and rainbow trout.

If an estimate of the rate of increase in length is known, expected daily percentage gains in weight for trout of various sizes may be calculated. These, multiplied by the proper conversion factor, give the amount of food to be fed daily in terms of percentage of body weight. These values are inversely proportional to the length.

When a pond holds a maximum population density of trout, the amount of food required will remain the same regardless of trout species, fish size or water temperature. Hence, that amount may be considered to be a single criterion of its carrying capacity. From it, one may calculate the quantity of trout that the pond will hold under various conditions, if the corresponding rates of increase in length are known. At different temperatures, the quantity of trout of a given size that may be held will differ. But, at a particular temperature, the permissible weights of trout of different sizes will be proportional to their lengths.

A temperature-unit system for studying growth when temperature varies is described, and its use for predicting the relative growth of trout when transferred from one hatchery to another is discussed. The application of statistics to trout growth data is also discussed.

From the studies reported in this paper the author has derived the following definition of trout growth in hatcheries.

> The normal growth of trout, under conditions of constant water temperature and adequate food supply, is such that the rate of increase in length is constant, except during times when metabolism is altered by factors such as disease, spawning, etc.

The data and reasoning leading to this definition will be presented first. Then, methods of estimating growth, based on the definition, will be given, and the relationship of such estimates to hatchery management will be discussed.

The objective is to develop practical methods for estimating the growth of trout raised under hatchery conditions with hatchery techniques. Those suggested are believed to be accurate enough to be used in most controlled studies of the relationship of nutrition to growth. However, the pure scientist will find that approximations have been made which violate, to a degree, certain of the more precise fishery concepts.

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[1] The author wishes to acknowledge advice from Dr. D. S. Robson, Assistant Professor of Biological Statistics at Cornell University.

FACTORS IN GROWTH

The growth rate of trout depends on a multiplicity of factors. Knowledge of trout growth in hatcheries has increased rapidly since the feeding chart system was inaugurated in 1933 by A. V. Tunison and C. R. Deuel. This system, most recently described by Deuel *et al.* (1952), has permitted the accumulation of records of growth and food utilization under the varied conditions of production hatcheries. These data will, one day, prove a fertile field of study for some student of growth. Experience with the system has already produced an entire generation of practical fish-culturists whose knowledge of trout growth probably exceeds that of earlier research workers. It seems appropriate to discuss some of the factors in growth, and to present the best available estimates of their effect.

Probably the most important is water temperature. Although temperature will be discussed in detail later, growth is nearly zero in water near the freezing point and increases rapidly as the temperature is increased. For brown trout, for example, data from production hatcheries indicate that growth increases at temperatures up to about 60° F., that it decreases at higher temperatures, and that above 70° F. it is very small.

Second only to temperature is care, although its specific features are extremely hard to define. Nonetheless growth rates under meticulously controlled conditions at the Cortland laboratory, and the growth rates of brook trout obtained in the experiment conducted by L. E. Wolf (Haskell *et al.*, 1956) under equally careful control, are seldom equalled at production hatcheries. Feeding practices which result in maximum ingestion of the food fed, careful attention to proper thinning, good aeration in ponds, prevention of undue accumulation of metabolic products, and cleanliness in ponds or raceways are certainly some of the elements of care. The hatchery foreman should recognize that, within the limits to which it is economically possible, care will pay off in increased growth.

Another important factor is the species of trout. Brook trout grow better at temperatures in the 40s than do brown trout. Also, the upper temperature limit for growth appears to be lower so that their growth-temperature relationship, while similar in form to that for brown trout, may be within a lower range in temperature. Further, it is well known that, within the optimum range, brook trout grow much faster than brown trout.

The strain of trout may also influence growth rate. In general, however, the usual hatchery strains seem to have much the same

growth potential. Wild trout introduced into a hatchery environment almost invariably have a slow growth rate. Also, trout which have existed for generations in unusual waters, such as extremely soft water, do not generally grow well in normal hatchery waters. Over a rather broad range, however, alkalinity, pH, etc. seem to have little effect on hatchery growth.

Diet affects growth. Certainly the diet must not be deficient in the components necessary for the physical well-being of trout. Progress in the field of nutrition is constantly being made. To date, the greatest advances have related chiefly to better food utilization and lower cost rather than increased growth. Recently, certain diet additives, such as cod liver oil, have been found to increase growth rates. Work now in progress by A. M. Phillips and his associates at the Cortland laboratory indicates that diets of greater growth potential may be possible. However, it must be emphasized that the diets developed over the past 30 years have produced only slight changes in growth rate under controlled laboratory experiments. Increased growth rates in hatcheries have, it is believed, resulted from better hatchery management and techniques rather than from improved diets.

Health is important in growth. During periods of disease growth rate unavoidably decreases, so that hatchery production is reduced beyond the actual loss of fish. Susceptibility to disease is related to physical well-being. The mere presence of a disease-producing organism often does not mean that an epidemic is imminent, unless some other factor is out of balance. Care, e.g., keeping fish at proper densities, proper feeding, etc., is a potent disease preventive and thus indirectly a factor in growth.

Trout growth is also affected by sexual maturity. During the periods preceding and following spawning, metabolism is altered so that normal growth cannot be expected. Meager as are the available data, they indicate that the rate of metabolism involved in egg production may slow the growth of female trout during their productive spawning years.

Summing up, trout growth rates are affected by water temperature, care, species, strain, diet, feeding level, health of fish, sexual maturity, and probably other factors. If rates of growth are different under seemingly comparable conditions, imbalance of any one of these factors may be the cause. Since some of them, particularly care, are hard to evaluate, cases will occur where the reason appears unaccountable.

In the following analysis only water temperature, species and

feeding level are considered. These factors are so powerful in affecting growth that they must be evaluated before critical studies of the others are possible. Data for trout under 1½ years old are used chiefly. The principles may apply to older trout, but data for such fish are insufficient.

GROWTH MECHANISM

Knowledge of animal nutrition has been of great use in providing starting points for studying trout nutrition. The growth of many animals is well understood, and mathematical approximations of the growth rates of certain ones are available. Most of the experimental work in animal husbandry has been on warm-blooded species.

Basically there are hereditary and environmental differences between the growth of warm-blooded, terrestrial animals and that of fish. First, trout are cold-blooded, and hence their body temperature and metabolism depend on the temperature of their environment. Second, in terrestrial animals growth appears to vary widely according to age. When maturity is reached growth stops, and the animal tends to remain at approximately the same size for the remainder of its life. In fish, however, there is reason to believe that normal growth may be continuous throughout life.

CONDITION FACTOR

The condition-factor concept states that the weight and length of fish are related by the equation:

$$W = KL^3$$

in which,

W = total weight
L = total length
K = condition factor

The implications of this equation are interesting since fish have a specific gravity of 1, i.e., their weight is the same as that of an equal volume of water.

The volume of a rectangular object is determined by its length, width, and height in the general equation:

$$V = L \times W \times H$$

For a fish, because of its irregular shape, the equation for volume would be complex. However, if the form of fish remained the same, the ratio between the volumes of a fish form and a rectangular form having equal over-all measurements would be the same. Thus volume

could be determined from the same equation by including a constant (C_1) to represent the ratio:

$$V = C_1 \times L \times W \times H$$

If the proportions of a fish remain the same as its size increases, then, if the length increases 1 per cent, the width and height will each increase 1 per cent also. It follows that the width equals the length times a second constant, and that the height equals the length times a third constant. Thus the equation ($V = C_1 \times L \times W \times H$) may be rewritten:

$$V = C_1 \times L \times (C_2 \times L) \times (C_3 \times L)$$

or $$V = C_1 \times C_2 \times C_3 \times L^3$$

Combining the constants, by letting $C_1 \times C_2 \times C_3 = K$, it becomes:

$$V = KL^3$$

In the metric system 1 cubic centimeter of water weighs 1 gram; therefore, volume in cubic centimeters is numerically equal to weight in grams. Substituting in the equation:

$$W = KL^3$$

which is the condition factor equation.

In the English system 27.68 cubic inches of water weigh 1 pound; hence:

$$W = 27.68\ KL^3$$

According to the condition-factor equation, therefore, the general shape of a fish remains proportional as its size increases, so that all dimensions increase at the same rate. It is interesting to combine the condition-factor concept with the theory that growth of fish continues throughout life. We may then envisage a fish as an object in which all parts of its body are continuously expanding at proportional rates throughout its life.

Although this seems a valuable way of thinking, it is only approximate since condition factors are not always constant. The condition factor (K) varies for different species, for different environmental conditions and food supplies, and for different ages as well as among individuals of the same lot. In general, however, under the hatchery environment it averages about the same for groups of trout.

Tunison, Kingsbury and Deuel (in the 1930's) analyzed a large collection of length-weight data taken in New York State hatcheries and prepared a table giving number of fish per pound *vs.* total length. They concluded that for hatchery purposes the same table might be used for brook trout, brown trout, and rainbow trout although a different table was required for lake trout. Experience over the years

has shown the accuracy of these figures to be high enough for hatchery purposes, and they are included in the New York State Feeding Chart (Deuel *et al.*, 1952).

The writer has calculated condition factors for the values in the first table and has found that the condition factor is nearly the same for all sizes except the 1-inch and ¾-inch groups. Because condition factors were not used in preparing the table, the fact that a single value very nearly fits all the data leads to the conclusion that for hatchery purposes the condition factor may be considered constant. For the two smallest groups it seems likely that the discrepancies were due to difficulty in properly removing the water from the fish. The equation that best fits these data is: $W = 0.0004055L^3$.

Although the fundamental equation states that weight equals the condition factor times the cube of the length, many fishery workers modify the equation. The modification consists of determining an exponent (e.g., 3.31) which makes the equation better fit the data being studied. In most cases the condition factor varies with age and size, particularly for wild fish, and sexual maturity. If the correct exponent is used the "condition factor" is made to remain the same. Thus this method obscures changes in condition for the purpose of mathematical convenience.

In changing to an odd power, the physical concept of a three-dimensional fish expanding proportionally in all dimensions is lost. The interpretation of data in a case where an odd power is used must be carefully differentiated from that in a case where the cube is used. Hile (1936) gave a detailed comparison of the interpretation of a condition factor under the two methods.

NORMAL GROWTH RATE

Evidence to support the definition of trout growth in hatcheries, as stated at the beginning of the paper, may be summarized as follows:

1. Haskell (1948) showed that, in the data compiled by Tunison and his associates in the annual reports of the Cortland Hatchery, the cube root of the mean weight produced a nearly straight line when plotted against time.
2. Haskell *et al.* (1956), in a study of the effect of temperature on the growth of brook trout, assumed that there was a different rate of increase of the cube root of the weight associated with each water temperature. The statistical success of analyzing a volume of data on this assumption makes its correctness convincing.

3. Haskell and Griffiths (1956) presented data which indicated that in a group of brook trout the increase in growth of individual fish is practically independent of the size of the individuals. Unpublished data indicate the same to be true for brown trout. Expanding this concept, the data indicated that, in brook trout up to 1½ years of age, males have a slightly higher growth rate than females, although the evidence to date indicates that this is not true in brown trout. When only one sex of a particular species, either brook trout or brown trout, is considered, the growth of individuals within a group appears to be random with an average tendency for that of the smallest fish to equal that of the largest. Thus the largest fish, which obviously grew fastest previously, may subsequently grow at a rapid rate, or at a low rate, or, most likely, at about the average rate for the group.

4. Brown (1957, pp. 372–376) and several other fisheries workers have advanced the theory that there exists in hatchery trout populations a "hierarchy" so that certain dominant individuals get the best of the food and the greatest quantity, and hence grow at a faster rate than normal. This phenomenon has been compared to the "peck order" in poultry. The data reported in the present paper are not adequate to determine whether or not such a hierarchy actually exists. However, if it does exist, and if its effect is reflected by growth rate, then it must be of a very transitory character. The fish having the most rapid growth rate at a particular time do not, on the average, continue at that rate. In addition, if a hierarchy exists, its members at any given time must include a representative cross-section of the population as regards size, since the most rapidly growing fish in a group include all sizes. But even if a peck order did exist it would be constantly shifting, so that over any extended period its effect on the growth of individuals would be negligible.

5. Various data indicate that for a given lot of trout the condition factor is reasonably constant throughout the first two years at least. The data compiled by Deuel *et al.* (1952) giving the length-weight relationship for hatchery trout support this finding. It follows directly that, if the condition factor is constant

and the cube root of the weight increases at a constant rate, the mean length does likewise, i.e.,

$$W = KL^3 \text{ and } \sqrt[3]{W} = \sqrt[3]{K}\, L$$

Thus, the cube root of the weight is proportional to the length.

6. Practical hatchery data (taken at the Rome Hatchery) indicate that, when brown trout are sorted and kept under similar environmental conditions, the increase in length over a 4-month period is almost exactly the same for the sorted groups (Table 1). For wild fish, examples may be found in the literature in which the increase in length was quite uniform for at least 2 years. On the other hand, a more common finding was that the increase in length decreased with each year of life. Although no proof exists, several factors that occur in the wild but not in hatcheries would seem to explain the decrease in growth. These include changes of diet with age, seasonal availability of food, effort and inclination to seek food, and competition for food by various size groups.

TABLE 1. COMPARATIVE GROWTH OF DIFFERENT-SIZED BROWN TROUT IN TWO REARING PONDS AT THE ROME HATCHERY

Date	Pond A			Pond B		
	Number per pound	Average length * (inches)	Increase in length	Number per pound	Average length * (inches)	Increase in length
June 15.....	144	2.578	.....	68.5	3.302	.....
October 1...	24.7	4.639	2.061	16.7	5.286	1.984

* Determined from number per pound according to data in Table 2.

MATHEMATICAL DERIVATIONS

To summarize the foregoing, hatchery trout, at a particular temperature, will remain constant in body form for at least 1½ years and increase in length at a constant rate. Also, the cube root of the average weight will increase at a constant rate. It is further indicated that a definite rate of increase in length may be derived for each water temperature for each species. These relationships make possible mathematical derivations important in estimating growth, gains, and feeding levels.

Since many of these derivations involve both length and weight,

a table of length *vs.* weight (in terms of number of fish per pound) for hatchery trout has been prepared (Table 2). It is based on a similar table compiled by Deuel *et al.* (1952) which, as has been mentioned, exhibited a nearly constant condition factor. The data presented here were derived from the equation:

$$W = 0.0004055L^3$$

in which,

W = weight in pounds
L = total length in inches

Lengths are expressed in thousandths of an inch. It must be added, at once, that there is no intent to imply that the figures given are absolute values accurate to this degree. On the other hand, it is intended that the table may be used to compute increases in growth over relatively short intervals. It is believed that for this purpose the differences in length listed are fairly reliable. The longer the period under study, the less reliance should be placed in the last decimal places.

Percentage Gain in Weight

If the rate of increase in length is constant it can be shown that the "instantaneous percentage gain" in weight is inversely proportional to the average length. This is demonstrated in the following equations.

$$(1)\ \text{percentage gain} = \frac{\text{gain}}{\text{weight at start}} \times 100$$

Applying calculus by letting dt represent a very short interval and dW the gain:

$$(2)\ \text{percentage gain} = \frac{1}{W} \times \frac{dW}{dt} \times 100$$

If $(3)\ W = KL^3$

and $(4)\ \frac{dW}{dt} = 3KL^2 \times \frac{dL}{dt}$

substituting (3) and (4) in (2) gives:

$$(5)\ \text{instantaneous percentage gain} = \frac{1}{KL^3} \times 3KL^2 \times \frac{dL}{dt} \times 100$$

$$= \frac{3}{L} \times \frac{dL}{dt} \times 100$$

Since, for fish growth, no serious error is introduced by assuming that one day is an "instant", then the daily percentage gain in weight is

TABLE 2. RELATIONSHIP OF WEIGHT TO LENGTH FOR BROOK TROUT, BROWN TROUT AND RAINBOW TROUT

Number per pound	Length in inches	Number per pound	Length in inches	Number per pound	Length in inches	Number per pound	Length in inches
6000	0.744	3350	0.903	1480	1.085	710	1.514
5950	0.745	3300	0.907	1460	1.191	700	1.522
5900	0.748	3250	0.912	1440	1.196	690	1.529
5850	0.750	3200	0.917	1420	1.202	680	1.536
5800	0.752	3150	0.922	1400	1.208	670	1.544
5750	0.754	3100	0.926	1380	1.213	660	1.552
5700	0.756	3050	0.932	1360	1.219	650	1.560
5650	0.758	3000	0.937	1340	1.225	640	1.568
5600	0.761	2950	0.942	1320	1.231	630	1.576
5550	0.763	2900	0.947	1300	1.238	620	1.584
5500	0.765	2850	0.953	1280	1.244	610	1.593
5450	0.768	2800	0.958	1260	1.251	600	1.602
5400	0.770	2750	0.964	1240	1.258	595	1.607
5350	0.772	2700	0.970	1220	1.264	590	1.611
5300	0.775	2650	0.976	1200	1.271	585	1.616
5250	0.777	2600	0.982	1180	1.278	580	1.620
5200	0.780	2550	0.989	1160	1.285	575	1.625
5150	0.782	2500	0.995	1140	1.293	570	1.629
5100	0.785	2450	1.002	1120	1.302	565	1.634
5050	0.788	2400	1.009	1100	1.309	560	1.639
5000	0.790	2350	1.016	1080	1.317	555	1.644
4950	0.793	2300	1.023	1060	1.325	550	1.649
4900	0.795	2250	1.031	1040	1.334	545	1.654
4850	0.798	2200	1.039	1020	1.342	540	1.659
4800	0.801	2150	1.047	1000	1.351	535	1.664
4750	0.804	2100	1.055	990	1.355	530	1.669
4700	0.806	2050	1.063	980	1.360	525	1.675
4650	0.809	2000	1.072	970	1.365	520	1.680
4600	0.812	1980	1.076	960	1.370	515	1.686
4550	0.815	1960	1.079	950	1.374	510	1.691
4500	0.818	1940	1.083	940	1.379	505	1.697
4450	0.821	1920	1.087	930	1.384	500	1.702
4400	0.824	1900	1.091	920	1.389	495	1.708
4350	0.828	1880	1.095	910	1.394	490	1.714
4300	0.831	1860	1.099	900	1.399	485	1.719
4250	0.834	1840	1.102	890	1.405	480	1.725
4200	0.837	1820	1.107	880	1.410	475	1.732
4150	0.841	1800	1.111	870	1.415	470	1.738
4100	0.844	1780	1.115	860	1.421	465	1.744
4050	0.848	1760	1.119	850	1.426	460	1.750
4000	0.851	1740	1.123	840	1.432	455	1.757
3950	0.855	1720	1.128	830	1.438	450	1.763
3900	0.858	1700	1.132	820	1.443	445	1.769
3850	0.862	1680	1.136	810	1.449	440	1.776
3800	0.866	1660	1.141	800	1.455	435	1.783
3750	0.870	1640	1.146	790	1.461	430	1.790
3700	0.873	1620	1.150	780	1.468	425	1.797
3650	0.877	1600	1.155	770	1.474	420	1.804
3600	0.881	1580	1.160	760	1.480	415	1.811
3550	0.886	1560	1.165	750	1.487	410	1.819
3500	0.890	1540	1.170	740	1.494	405	1.826
3450	0.894	1520	1.175	730	1.500	400	1.834
3400	0.898	1500	1.180	720	1.507	398	1.837

Table 2. (*continued*)

Number per pound	Length in inches	Number per pound	Length in inches	Number per pound	Length in inches	Number per pound	Length in inches
396	1.840	290	2.041	192	2.342	139	2.608
394	1.843	288	2.046	191	2.346	138	2.614
392	1.846	286	2.051	190	2.350	137	2.620
390	1.849	284	2.055	189	2.354	136	2.627
388	1.852	282	2.060	188	2.358	135	2.633
386	1.855	280	2.065	187	2.362	134	2.640
384	1.859	278	2.070	186	2.367	133	2.647
382	1.862	276	2.075	185	2.371	132	2.654
380	1.865	274	2.080	184	2.375	131	2.660
378	1.869	272	2.085	183	2.379	130	2.667
376	1.872	270	2.090	182	2.384	129	2.674
374	1.875	268	2.095	181	2.388	128	2.681
372	1.878	266	2.101	180	2.393	127	2.688
370	1.882	264	2.106	179	2.397	126	2.695
368	1.885	262	2.111	178	2.402	125	2.702
366	1.889	260	2.117	177	2.406	124	2.709
364	1.892	258	2.122	176	2.411	123	2.717
362	1.896	256	2.127	175	2.415	122	2.724
360	1.899	254	2.133	174	2.420	121	2.731
358	1.901	252	2.139	173	2.424	120	2.739
356	1.906	250	2.144	172	2.429	119	2.746
354	1.910	248	2.150	171	2.434	118	2.754
352	1.913	246	2.156	170	2.439	117	2.762
350	1.917	244	2.162	169	2.443	116	2.770
348	1.921	242	2.168	168	2.448	115	2.778
346	1.924	240	2.174	167	2.453	114	2.786
344	1.928	238	2.180	166	2.458	113	2.794
342	1.932	236	2.186	165	2.463	112	2.803
340	1.936	234	2.192	164	2.468	111	2.811
338	1.939	232	2.198	163	2.473	110	2.820
336	1.943	230	2.205	162	2.478	109	2.828
334	1.947	228	2.211	161	2.483	108	2.837
332	1.951	226	2.218	160	2.488	107	2.846
330	1.955	224	2.225	159	2.493	106	2.854
328	1.959	222	2.231	158	2.499	105	2.863
326	1.963	220	2.238	157	2.504	104	2.873
324	1.967	218	2.245	156	2.510	103	2.882
322	1.971	216	2.252	155	2.515	102	2.892
320	1.975	214	2.259	154	2.521	101	2.901
318	1.979	212	2.266	153	2.526	100	2.910
316	1.983	210	2.273	152	2.531	99.5	2.915
314	1.988	208	2.280	151	2.537	99.0	2.920
312	1.992	206	2.288	150	2.543	98.5	2.925
310	1.996	204	2.295	149	2.548	98.0	2.931
308	2.000	202	2.303	148	2.554	97.5	2.935
306	2.005	200	2.310	147	2.560	97.0	2.940
304	2.009	199	2.314	146	2.566	96.5	2.945
302	2.014	198	2.318	145	2.572	96.0	2.950
300	2.018	197	2.322	144	2.578	95.5	2.955
298	2.023	196	2.326	143	2.584	95.0	2.961
296	2.027	195	2.330	142	2.590	94.5	2.966
294	2.032	194	2.334	141	2.596	94.0	2.971
292	2.036	193	2.338	140	2.602	93.5	2.977

TABLE 2. (*continued*)

Number per pound	Length in inches	Number per pound	Length in inches	Number per pound	Length in inches	Number per pound	Length in inches
93.0	2.982	66.5	3.334	40.0	3.950	29.4	4.378
92.5	2.987	66.0	3.343	39.8	3.957	29.2	4.388
92.0	2.993	65.5	3.351	39.6	3.963	29.0	4.398
91.5	2.998	65.0	3.360	39.4	3.970	28.8	4.408
91.0	3.004	64.5	3.369	39.2	3.977	28.6	4.418
90.5	3.009	64.0	3.378	39.0	3.984	28.4	4.428
90.0	3.015	63.5	3.387	38.8	3.991	28.2	4.438
89.5	3.020	63.0	3.395	38.6	3.997	28.0	4.448
89.0	3.026	62.5	3.404	38.4	4.004	27.8	4.460
88.5	3.031	62.0	3.413	38.2	4.011	27.6	4.470
88.0	3.037	61.5	3.422	38.0	4.018	27.4	4.481
87.5	3.043	61.0	3.432	37.8	4.026	27.2	4.493
87.0	3.049	60.5	3.441	37.6	4.033	27.0	4.503
86.5	3.055	60.0	3.450	37.4	4.040	26.8	4.514
86.0	3.061	59.5	3.460	37.2	4.047	26.6	4.526
85.5	3.067	59.0	3.470	37.0	4.055	26.4	4.537
85.0	3.073	58.5	3.480	36.8	4.062	26.2	4.549
84.5	3.078	58.0	3.490	36.6	4.069	26.0	4.561
84.0	3.084	57.5	3.500	36.4	4.077	25.8	4.572
83.5	3.090	57.0	3.510	36.2	4.084	25.6	4.584
83.0	3.097	56.5	3.520	36.0	4.091	25.4	4.595
82.5	3.103	56.0	3.531	35.8	4.099	25.2	4.608
82.0	3.110	55.5	3.541	35.6	4.106	25.0	4.620
81.5	3.116	55.0	3.552	35.4	4.114	24.8	4.633
81.0	3.122	54.5	3.563	35.2	4.123	24.6	4.646
80.5	3.128	54.0	3.574	35.0	4.130	24.4	4.659
80.0	3.135	53.5	3.585	34.8	4.138	24.2	4.670
79.5	3.141	53.0	3.597	34.6	4.145	24.0	4.684
79.0	3.148	52.5	3.608	34.4	4.154	23.8	4.697
78.5	3.155	52.0	3.619	24.2	4.162	23.6	4.710
78.0	3.162	51.5	3.631	34.0	4.170	23.4	4.724
77.5	3.169	51.0	3.643	33.8	4.179	23.2	4.737
77.0	3.176	50.5	3.655	33.6	4.186	23.0	4.750
76.5	3.182	50.0	3.667	33.4	4.196	22.8	4.764
76.0	3.189	49.5	3.679	33.2	4.203	22.6	4.779
75.5	3.196	49.0	3.692	33.0	4.211	22.4	4.792
75.0	3.204	48.5	3.705	32.8	4.220	22.2	4.806
74.5	3.211	48.0	3.718	32.6	4.228	22.0	4.821
74.0	3.218	47.5	3.730	32.4	4.238	21.8	4.835
73.5	3.225	47.0	3.743	32.2	4.247	21.6	4.850
73.0	3.233	46.5	3.756	32.0	4.255	21.4	4.867
72.5	3.240	46.0	3.770	31.8	4.264	21.2	4.881
72.0	3.248	45.5	3.784	31.6	4.273	21.0	4.897
71.5	3.255	45.0	3.798	31.4	4.282	20.8	4.913
71.0	3.262	44.5	3.812	31.2	4.292	20.6	4.929
70.5	3.270	44.0	3.827	31.0	4.301	20.4	4.943
70.0	3.278	43.5	3.842	30.8	4.309	20.2	4.961
69.5	3.286	43.0	3.857	30.6	4.319	20.0	4.978
69.0	3.294	42.5	3.872	30.4	4.329	19.9	4.985
68.5	3.302	42.0	3.887	30.2	4.338	19.8	4.994
68.0	3.310	41.5	3.902	30.0	4.348	19.7	5.002
67.5	3.318	41.0	3.918	29.8	4.358	19.6	5.011
67.0	3.326	40.5	3.934	29.6	4.368	19.5	5.018

Table 2. (*continued*)

Number per pound	Length in inches	Number per pound	Length in inches	Number per pound	Length in inches	Number per pound	Length in inches
19.4	5.028	14.55	5.535	11.90	5.918	9.25	6.436
19.3	5.037	14.50	5.539	11.85	5.925	9.20	6.449
19.2	5.045	14.45	5.546	11.80	5.933	9.15	6.458
19.1	5.054	14.40	5.553	11.75	5.944	9.10	6.470
19.0	5.064	14.35	5.560	11.70	5.951	9.05	6.483
18.9	5.071	14.30	5.567	11.65	5.959	9.00	6.495
18.8	5.081	14.25	5.573	11.60	5.967	8.95	6.508
18.7	5.090	14.20	5.578	11.55	5.978	8.90	6.520
18.6	5.098	14.15	5.585	11.50	5.986	8.85	6.533
18.5	5.108	14.10	5.592	11.45	5.994	8.80	6.544
18.4	5.117	14.05	5.599	11.40	6.002	8.75	6.555
18.3	5.127	14.00	5.606	11.35	6.012	8.70	6.568
18.2	5.137	13.95	5.613	11.30	6.020	8.65	6.581
18.1	5.145	13.90	5.620	11.25	6.028	8.60	6.593
18.0	5.154	13.85	5.624	11.20	6.039	8.55	6.606
17.9	5.164	13.80	5.631	11.15	6.047	8.50	6.619
17.8	5.174	13.75	5.639	11.10	6.056	8.45	6.632
17.7	5.184	13.70	5.646	11.05	6.066	8.40	6.645
17.6	5.194	13.65	5.653	11.00	6.075	8.35	6.658
17.5	5.204	13.60	5.660	10.95	6.083	8.30	6.672
17.4	5.214	13.55	5.667	10.90	6.094	8.25	6.685
17.3	5.224	13.50	5.674	10.85	6.102	8.20	6.701
17.2	5.234	13.45	5.681	10.80	5.113	8.15	6.715
17.1	5.244	13.40	5.688	10.75	6.121	8.10	6.728
17.0	5.253	13.35	5.696	10.70	6.130	8.05	6.741
16.9	5.265	13.30	5.703	10.65	6.141	8.00	6.755
16.8	5.275	13.25	5.710	10.60	6.149	7.95	6.768
16.7	5.286	13.20	5.717	10.55	6.160	7.90	6.782
16.6	5.296	13.15	5.724	10.50	6.169	7.85	6.799
16.5	5.306	13.10	5.732	10.45	6.180	7.80	6.813
16.4	5.317	13.05	5.739	10.40	6.189	7.75	6.827
16.3	5.327	13.00	5.746	10.35	6.200	7.70	6.840
16.2	5.340	12.95	5.754	10.30	6.209	7.65	6.858
16.1	5.350	12.90	5.761	10.25	6.220	7.60	6.872
16.0	5.361	12.85	5.768	10.20	6.229	7.55	6.886
15.9	5.372	12.80	5.776	10.15	6.240	7.50	6.903
15.8	5.385	12.75	5.783	10.10	6.249	7.45	6.917
15.7	5.395	12.70	5.791	10.05	6.260	7.40	6.932
15.6	5.406	12.65	5.798	10.00	6.272	7.35	6.949
15.5	5.419	12.60	5.806	9.95	6.281	7.30	6.964
15.4	5.430	12.55	5.813	9.90	6.293	7.25	6.982
15.3	5.441	12.50	5.821	9.85	6.301	7.20	6.996
15.2	5.454	12.45	5.828	9.80	6.313	7.15	7.014
15.1	5.465	12.40	5.836	9.75	6.325	7.10	7.029
15.0	5.478	12.35	5.846	9.70	6.334	7.05	7.047
14.95	5.483	12.30	5.854	9.65	6.346	7.00	7.062
14.90	5.490	12.25	5.861	9.60	6.358	6.95	7.079
14.85	5.496	12.20	5.869	9.55	6.367	6.90	7.096
14.80	5.503	12.15	5.876	9.50	6.379	6.85	7.113
14.75	5.510	12.10	5.884	9.45	6.391	6.80	7.131
14.70	5.514	12.05	5.892	9.40	6.409	6.75	7.148
14.65	5.521	12.00	5.902	9.35	6.412	6.70	7.166
14.60	5.528	11.95	5.910	9.30	6.424	6.65	7.184

TABLE 2. (*continued*)

Number per pound	Length in inches	Number per pound	Length in inches	Number per pound	Length in inches	Number per pound	Length in inches
6.60	7.202	5.65	7.585	4.75	8.037	3.85	8.620
6.55	7.221	5.60	7.608	4.70	8.065	3.80	8.657
6.50	7.239	5.55	7.631	4.65	8.094	3.75	8.696
6.45	7.257	5.50	7.654	4.60	8.123	3.70	8.735
6.40	7.277	5.45	7.677	4.55	8.153	3.65	8.774
6.35	7.296	5.40	7.701	4.50	8.183	3.60	8.815
6.30	7.315	5.35	7.724	4.45	8.214	3.55	8.856
6.25	7.334	5.30	7.749	4.40	8.245	3.50	8.898
6.20	7.354	5.25	7.773	4.35	8.276	3.45	8.941
6.15	7.374	5.20	7.798	4.30	8.308	3.40	8.984
6.10	7.394	5.15	7.823	4.25	8.340	3.35	9.029
6.05	7.414	5.10	7.849	4.20	8.374	3.30	9.074
6.00	7.435	5.05	7.874	4.15	8.407	3.25	9.121
5.95	7.455	5.00	7.901	4.10	8.441	3.20	9.168
5.90	7.476	4.95	7.927	4.05	8.476	3.15	9.216
5.85	7.498	4.90	7.954	4.00	8.511	3.10	9.265
5.80	7.519	4.85	7.981	3.95	8.546	3.05	9.316
5.75	7.541	4.80	8.009	3.90	8.583	3.00	9.368
5.70	7.563						

inversely proportional to the length, and equation (5) may be rewritten:

$$(6)\ \text{daily percentage gain} = \frac{3}{L} \times \Delta L \times 100$$

in which,

ΔL = daily length increase
L = total length

Thus the daily percentage gain for 2-inch fish should be half, and that for 6-inch fish one-sixth, that for 1-inch fish under the same conditions. Hence a method is available for comparing percentage gains for fish of various sizes. The comparison must be on a daily rather than a monthly basis, however. For this and several other reasons which will be shown later, it is regrettable that the feeding chart system was not based on daily rather than monthly percentage gains.

If an estimate of the rate of increase in length is known, expected percentage gains in weight for trout of various sizes may be calculated. To illustrate, data for brook trout growth (Haskell *et al.*, 1956) may be used. The expected increases in length are given in Table 3, and the expected daily percentage gains in Table 4.

The expected gains predicted by these tables are based on data taken under nearly optimum conditions of care. Such gains are

Table 3. Expected Increases in Length of Brook Trout at Various Water Temperatures

Temperature in degrees Fahrenheit	Daily increase in length in inches
42	0.0069
44	0.0111
46	0.0152
48	0.0193
50	0.0234
52	0.0276
54	0.0317

Table 4. Expected Daily Percentage Gain in Weight for Brook Trout of Various Sizes at Different Water Temperatures*

Temperature in degrees Fahrenheit	Length in inches						
	1	2	3	4	5	6	7
42	2.07	1.04	0.69	0.52	0.42	0.35	0.30
44	3.33	1.67	1.11	0.83	0.67	0.56	0.48
46	4.56	2.28	1.52	1.14	0.91	0.76	0.65
48	5.79	2.89	1.93	1.45	1.16	0.97	0.83
50	7.02	3.51	2.34	1.75	1.40	1.17	1.00
52	8.28	4.14	2.76	2.07	1.66	1.38	1.18
54	9.51	4.75	3.17	2.38	1.90	1.59	1.36

* Figures to left and below dotted lines beyond range of data on which table was based.

rarely obtained in production hatcheries. However, at a given hatchery, for example, if gains of 75 per cent of the tabulated value are attained at one temperature and one size, approximately the same percentage of the tabulated value may be expected at other temperatures and sizes.

Percentage of Body Weight to Be Fed Daily

The basic equation for pounds of food to be fed daily in terms of percentage of body weight is:

$$(7)\ \text{percentage of body weight} = \frac{200 \times \text{Conv.} \times \text{percentage gain}}{(200 + \text{percentage gain}) \times \text{days}}$$

in which,

percentage gain = that for the number of days in the denominator
Conv. = conversion factor

If daily percentage gain is used, the number of days is one. Also, since the daily percentage gain rarely exceeds 5 per cent, the term

"200 + percentage gain" in the denominator may be changed to "200", with a maximum error of only 2.5 per cent in the resulting percentage of body weight. In this case the equation becomes:

$$(8)\ \text{percentage of body weight} = \frac{200 \times \text{Conv.} \times \text{percentage gain}}{200 \times 1}$$

This equation simplifies to:

$$(9)\ \text{percentage of body weight} = \text{Conv.} \times \text{daily percentage gain}$$

The equation[1] in this form permits mental calculations of the amount to feed, if the expected daily percentage gain is known. Because of this simplicity it may well pay fish-culturists to change their thinking from monthly percentage gains to the equivalent daily values.

TABLE 5. SUGGESTED AMOUNT PER DAY, IN PERCENTAGE OF BODY WEIGHT, TO FEED BROOK TROUT OF VARIOUS SIZES AT DIFFERENT WATER TEMPERATURES*

Temperature in degrees Fahrenheit	Length in inches						
	1	2	3	4	5	6	7
42.....	6.2	3.1	2.1	1.6	1.3	1.0	0.9
44.....	10.0	5.0	3.3	2.5	2.0	1.7	1.4
46.....	13.7	6.8	4.6	3.4	2.7	2.3	1.9
48.....	17.4	8.7	5.8	4.3	3.5	2.9	2.5
50.....	21.1	10.5	7.0	5.2	4.2	3.5	3.0
52.....	24.8	12.4	8.3	6.2	5.0	4.1	3.5
54.....	28.5	14.2	9.5	7.1	5.7	4.8	4.1

* Figures to left and below dotted lines beyond range of data on which table was based.

In Table 5 suggested feeding levels, in terms of percentage of body weight, are given to correspond to expected gains as given in Table 4. A conversion factor of 3.0 has been assumed since, for an all-meat diet, experience has shown this to be a reasonable ratio. Therefore, the figures in Table 5 are three times those in Table 4. The figures for 1-inch fish and for 54° F., to the left and below the dotted lines, go beyond the range of the data on which the table was

[1] Equations (7) and (9) both depend on the assumption that the average weight of fish on hand equals the average of the weight on hand at the start and that at the end of the period considered. Since this is not quite true, both equations should be considered as close approximations of the true result, equation (9) being the better.

based and hence should be regarded with caution. Experience at the Rome Hatchery has indicated that the amount of food suggested in this table for 1-inch fish cannot be ingested within an 8-hour day, but that by feeding over a 24-hour day the amount eaten and the gains attained can be greatly increased. The advantage of the 24-hour feeding seems to exist only until the fish reach about 1,000 per pound.

If equations (6) and (9) are combined and a conversion of 3 assumed:

$$(10)\ \text{percentage of body weight} = \frac{9}{L} \times \Delta L \times 100$$

To illustrate, if under certain conditions trout are known to gain in length at the rate of ½ inch per month, then the daily increase in length is $0.5 \div 31 = 0.0161$. If a lot of 2-inch trout is held under these conditions:

$$(11)\ \text{percentage of body weight} = \frac{9 \times 0.0161 \times 100}{2} = 7.25$$

Population Densities

Haskell (1955) suggested using the amount of food required daily as a measure of the carrying capacity of a hatchery pond. He theorized that the consumption of oxygen and the production of metabolic wastes are both proportional to the amount of food. Thus, if the amount of food required is known for a pond that is believed to support a maximum trout population density, then this same amount would represent the limit for other trout species, fish sizes, and water temperatures. Hence, the factors governing permissible densities may be combined in a single criterion. The continued use of this method at the Rome Hatchery, where average monthly water temperatures vary from 34° to 75° F., has given increasing confidence in its validity.

The use of weight of food as a measure of carrying capacity may be shown by the following equations.

$$(12)\ \text{weight of food required daily} = \text{percentage of body weight} \times \text{weight of fish}$$

In equation (10) it was shown that, for a given set of conditions, the percentage of body weight to be fed is inversely proportional to the average length. Therefore, letting C represent the constant $(9 \times \Delta L \times 100)$:

$$(13)\ \text{weight of food required daily} = \frac{C}{L} \times \text{weight of fish}$$

If the maximum daily weight of food (F) has been determined for a particular pond and is substituted in this equation:

$$(14)\quad F = \frac{C}{L} \times \text{weight of fish}$$

The equation may be rewritten:

$$(15)\quad \text{weight of fish} = \frac{F}{C} \times L$$

or, letting A represent the two constants combined:

$$(16)\quad \text{weight of fish} = AL$$

The last equation states that, at a particular temperature, the maximum permissible weight of fish in a given pond is directly proportional to their length. Thus, if the pond could safely hold 100 pounds of 2-inch fish, it could hold 200 pounds of 4-inch fish, 300 pounds of 6-inch fish, etc.

As the temperature varies the permissible density for trout of the same size will also vary. But, for trout of different sizes, the allowable pounds of fish per cubic foot of water will be proportional to length at any given temperature.

GROWTH PREDICTION

The foregoing mathematical discussion will in no way affect the methods of calculation used in preparing the standard feeding chart. It is hoped, rather, that it will contribute to a new way of thinking of trout growth and hatchery management—in terms of growth as measured by length, percentage of body weight to be fed as inversely proportional to length, simplified equations for quick estimation when daily rather than monthly percentage gains are used, population densities as related to length of fish.

These principles are also applicable to growth prediction. Frequently it is desired to predict the future performance of a group of trout or of an entire hatchery based on the stock on hand. Or it may be desired to evaluate past growth or to compare hatcheries. The concept of a constant rate of increase in length at each water temperature facilitates such comparisons. For example, if one knows the size of the trout on hand and can assume that the sequence of temperatures during an ensuing period will be the same as in some past period, then, if the increase in length for that period is known, the expected increase for the future period may be estimated. This increase added to the length of the fish on hand will give an estimate

of the size of the fish at the end of the period being considered. By other methods such predictions are complicated by the fact that the trout on hand one year are seldom the same size as those another year for a variety of reasons, and most other estimates of growth are affected by fish size.

As a second example, if the annual series of monthly temperatures is nearly the same for successive years, then: (1) one may expect a nearly constant increase in length during a year, irrespective of the initial size of the fish; and (2) one may also think in terms of an expected increase in length for each month for each species at a given station.

TEMPERATURE UNITS

The foregoing discussion has dealt principally with trout growth under conditions of constant temperature. Hatchery temperatures are seldom constant, and for this reason a temperature-unit system has been devised for studying growth when the temperature varies.

As a basis for this method the brook trout data collected by Wolf (Haskell *et al.*, 1956) have again been used. They indicated that over a temperature range of 42° to 52° F. the rate of increase in length was linearly related to water temperature. If the expected rate of increase in length were plotted against temperature, a straight line drawn through the points and extended would indicate zero growth at 38.6° F. The temperature-unit system has been built around this as the threshold of growth.

Before describing the system it should be pointed out that we do not believe that growth actually stops at 38.6° F. On the other hand, the straight line which depicts increase in length for the range of 42° to 52° F., when extended for mathematical purposes does intersect zero at 38.6° F. It is expected that, if data were available to extend the growth line accurately to the lower temperatures, it would prove to be a curved line below 42° F., and possibly not reach zero until the low 30s in temperature. However, in growth estimation, if a few very low temperatures appear in a series consisting principally of high temperatures, no serious error will be introduced if it is assumed that growth is zero below 38.6° F. since it certainly would be extremely small.

A temperature unit has been defined as an average water temperature for a month, exceeding 38.6° F. by one degree. Thus, in general:

$$T.\ U. = (\text{average water temperature} - 38.6)\ \text{months}.$$

For example, at a temperature of 46° F. for 1 month:

$$T.\ U. = 46 - 38.6 = 7.4$$

Also, at a temperature of 42.3° F. for 2 months:

$$T.\ U. = (42.3 - 38.6) \times 2 = 7.4$$

Thus the expected growth in 1 month at 46° F. is the same as that in 2 months at 42.3° F.

By this method the growth of five hatchery lots of brook trout has been plotted using length *vs.* temperature units on a cumulative basis (Figures 1–5). Lengths were determined from the numbers per pound recorded using the data in Table 2. The only selection in choosing these particular lots was to include only lots which had been carried several months without shipments or unusual mortalities.

In Figure 6 growth data for all of the five lots are plotted to illus-

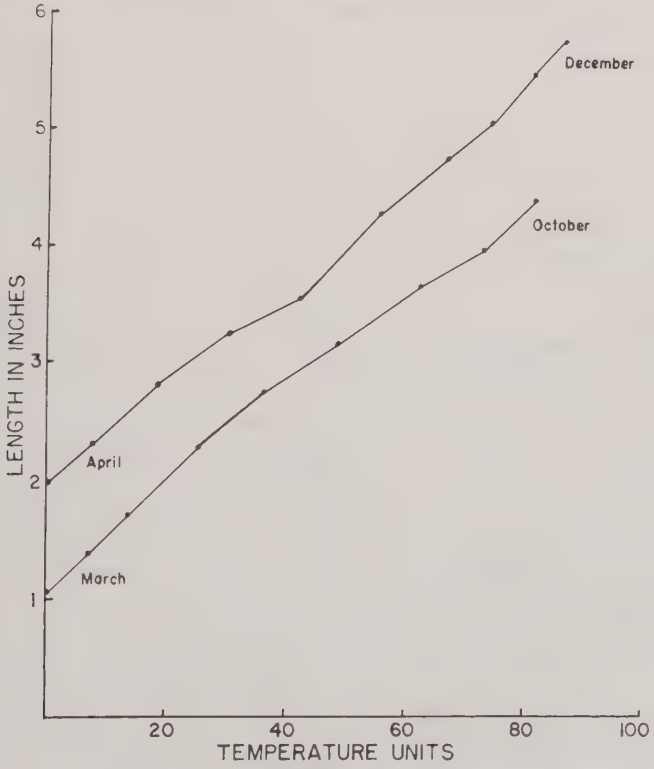

Figure 1. Growth rates of two lots of brook trout in relation to cumulative temperature units at the Van Hornesville Hatchery.

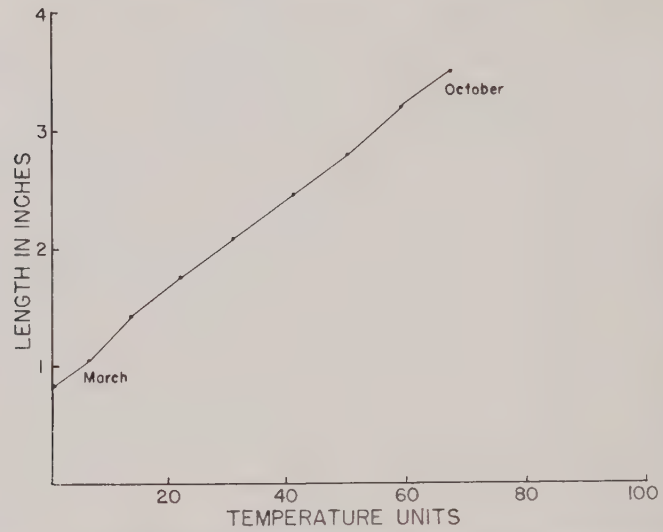

Figure 2. Growth rate of one lot of brook trout in relation to cumulative temperature units at the Chateaugay Hatchery.

trate the similarity of the slopes of the several lines. Also in the lower left corner are shown the slopes predicted by Wolf's data and by data from the Cortland laboratory. The latter are considered to be near the maximum growth rate obtainable with present diets, and the fact that the production hatchery data have a rather uniformly lesser slope is probably due to differences in care.

If temperature units as here described are extensively used, the "threshold" temperature of 38.6° F. may require revision as better data become available. If a threshold temperature were known for them, a similar system might be tried for other species.

Two of the possible uses of a temperature-unit system may be of interest. First, it appears from the graphs that about 21 units are required for an inch of growth for brook trout in the production hatcheries. In New York State an objective is to produce 7-inch trout by the opening of the fishing season in their second year. Thus about 15 months are available to bring brook trout from ¾-inch to 7 inches (January 1 to April 1 of the next year). This increase in length of 6¼ inches would require about 130 units. The temperature units available at four State hatcheries having widely different temperatures have been calculated based on records for 1955–1956 (Table 6). These results seem to be in line with the performance of these hatcheries.

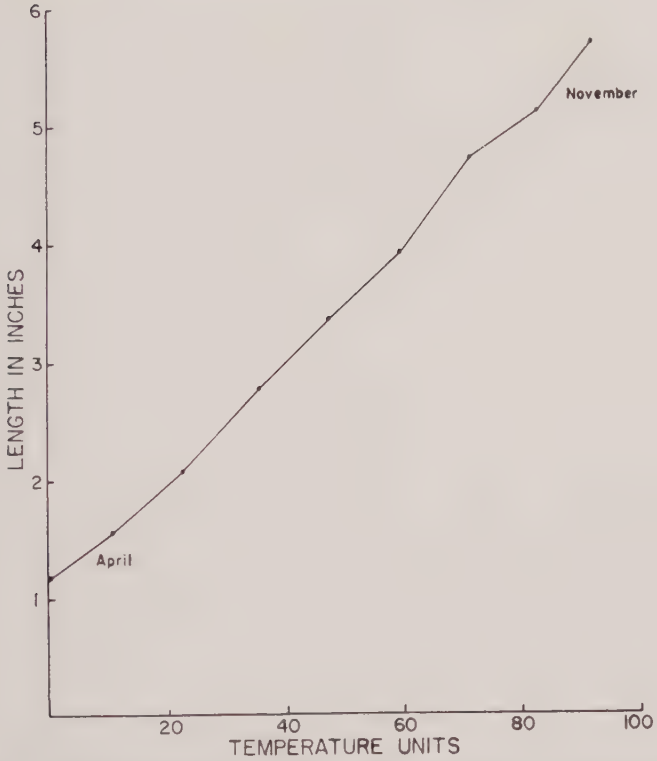

Figure 3. Growth rate of one lot of brook trout in relation to cumulative temperature units at the Bath Hatchery.

TABLE 6. TEMPERATURE UNITS AVAILABLE AND EXPECTED GROWTH OF BROOK TROUT FOR FOUR NEW YORK FISH HATCHERIES*

Hatchery	Average temperature in degrees Fahrenheit	Temperature units	Expected growth in inches
A	48.3	145.0	¾ to 7¾
B	45.6	107.6	¾ to 6
C	43.5	74.4	¾ to 4¼
D	42.6	70.9	¾ to 4¼

* For 15-month period from January 1 to April 1 of next year.

As a second example, suppose it were desired to transfer brook trout from hatchery A to hatchery B at the earliest possible date and still produce 7-inch fish by April 1. Total temperature units would

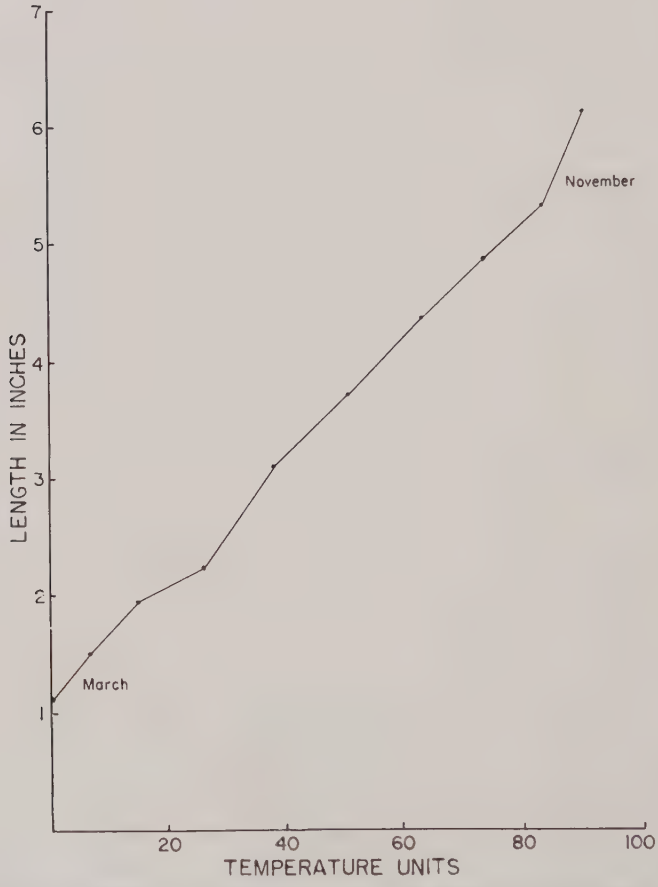

Figure 4. Growth rate of one lot of brook trout in relation to cumulative temperature units at the Randolph Hatchery.

be the sum of those at hatchery A prior to the transfer and those at hatchery B after the transfer. Although the details will not be given, with the monthly values known, it is easy to calculate that the earliest date for such a transfer would be October 1. Prior to that the temperature units at hatchery A would equal 96.1, and afterwards the units at hatchery B would equal 32.9, or a total of 129.

A similar computation indicates that to make a transfer from hatchery A to either hatcheries B or C, and to have 7-inch fish available by April 1, would require growing them to 7 inches before the transfer, because they would add practically no growth at the low winter temperature at hatcheries B and C.

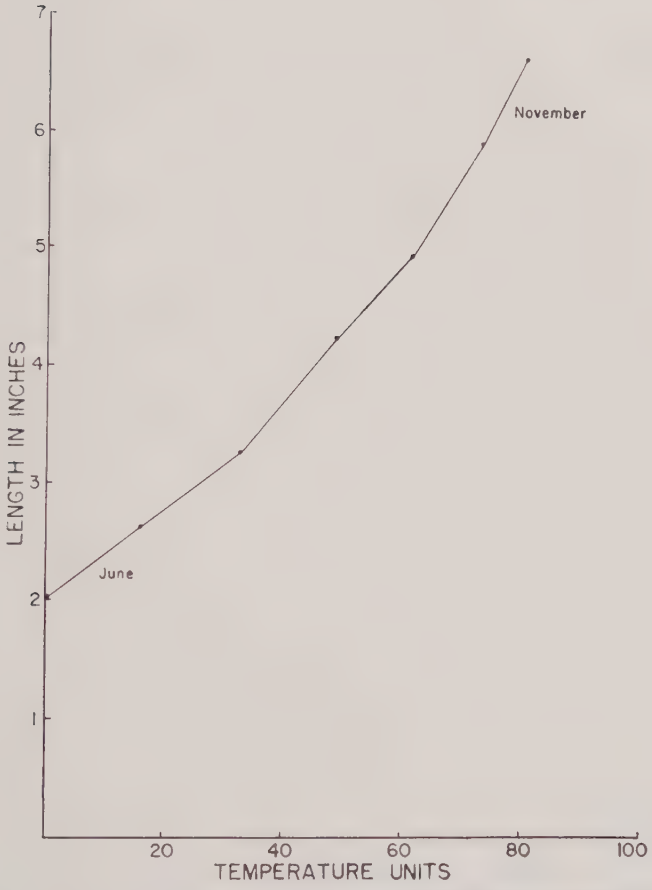

Figure 5. Growth rate of one lot of brook trout in relation to cumulative temperature units at the Lily Lake Hatchery.

APPLICATION OF STATISTICS TO TROUT GROWTH DATA

Several other problems arise when critical growth comparisons are to be made. These have little interest to the practical fish-culturist, but are discussed for the benefit of those engaged in experimental work.

The use of statistics in analyzing numerical data has become widespread in recent years. A scientist, today, can hardly afford to ignore their possibilities. The choice of whether or not to use such methods lies with the person conducting the experiment and his decision should be based on: (1) whether or not he can achieve results

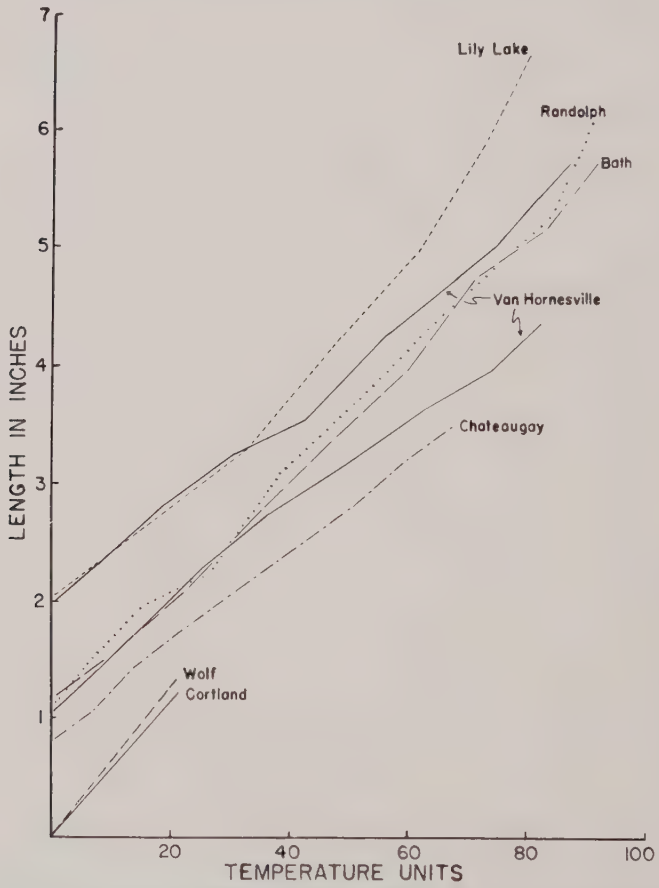

Figure 6. Composite of growth rates illustrated in Figures 1-5 with slopes predicted by Wolf's data and by data from the Cortland laboratory also shown.

which will convince himself and others in his field of their validity without a statistical analysis; (2) whether the application of statistical technique will require such changes in the method of conducting the experiment as to unreasonably increase the cost.

Application of statistical methods to agricultural experimentation has increased the precision and reliability of comparative tests of crops and treatments. That similar techniques might accomplish increased precision in trout growth experiments has been recognized for some time. In the present discussion, various aspects of statistical treatment will be reviewed, without pretense of completeness.

Use of statistics in any field requires that certain principles be followed in conducting the experiment. These may be compared to the rules of a game, and it is apparent that the results cannot be analyzed unless these principles are followed, just as in a game the winner could not be determined were the rules of play disregarded. Whether or not statistics are applied to a problem will depend primarily on whether the required principles can be incorporated in the experimental technique.

If statistical methods are to be applied in a field where experimentation has proceeded for some time, certain changes in experimental technique will usually be required. It is not implied that such changes indicate a faulty technique in previous work, but that they are required merely to comply with the basis of statistical reasoning.

Growth experiments with trout are usually conducted to compare two or more diets or strains, etc. To illustrate the method, a typical experiment comparing two diets will be used. It has been customary to set up such an experiment by establishing equal populations in ten or more troughs, assigning half of them to one diet and half to the other. This assignment is made in a random manner, or at least should be. The experiment is conducted in 2-week periods, and the total weight of the population of each trough is taken at the end of each period. The experiment may run for from one to twelve periods, and at the end the data for each period are tabulated and studied. The tabulation may be of several types. For example, the average weight per fish at the end of each period may be given. Then a comparison for the two lots under study may indicate the superiority of one diet over the other. A second method of presenting the data is to compute the percentage gain for each lot for each period and compare the averages or means of these percentages.

When statistics are applied to such data several additional points must be taken into account. In general, statistical technique is applicable to the comparison of groups of data in which each item is independent of each other item. For a given lot of fish the gain in one period may influence the gain in following periods. Thus the data for a single lot in successive periods are not independent. Comparisons of the results in one period with those in another period cannot be made. At the beginning of the experiment, however, the fish were assigned to the lots in a random manner, and the diets were also assigned at random. Thus, each lot is independent of each other lot, and growth within the same time interval may be compared statistcally. A comparison of the size attained by the various lots at the end of the

experiment lends itself readily to statistical tests. Likewise a comparison might be made at the end of any period during the experiment, the data recorded subsequently being disregarded.

Snedecor[2] has stated this requirement succinctly ". . . the measurements of weight in successive two-week periods are probably not independent, since lots getting a good start tend to maintain and even increase the lead in subsequent periods. In the analysis of variance among periods, among lots and discrepance, the latter may be biased downward as an estimate of real experimental error. This consequence of 'serial correlation' must be avoided in growth studies as well as in economic time series. Ordinarily it is satisfactory in experiments such as you describe to test significance only at the end of the experiment, using *total attained weight* or *mean growth weight* as the variate".

As an example we may use data collected by Tunison *et al.* (1939, p. 16). To test the variability to be expected in nutrition trials, six lots were given identical treatment for 24 weeks. The published data comprise a table of the weight attained by each lot at the end of each 2-week period. According to the foregoing principles one may compare the final attained weights, the degrees of freedom for the analysis being divided as follows:

number of lots	6
degrees of freedom	5

This is far different from the case which would exist if successive periods were independent. If this were true the analysis would be as follows:

number of items (lots × periods)	72
degrees of freedom	71

In this experiment where only one diet was used no comparisons are necessary. Had two diets been used, each in three troughs, the degrees of freedom would have been:

number of lots	6
degrees of freedom	
total	5
diets	1
error	4

If one computes the standard error of the mean for the final weights in Tunison's data, it will be seen that the experimental vari-

[2] George W. Snedecor, Iowa State College, personal communication, 1942.

ation is large and that the method of test is somewhat insensitive. This may be attributed to the large normal variation to be expected in the lots, and to the small number of replications. As previously pointed out, instead of comparing the results at the end of 24 weeks, those at the end of any other period might have been used, provided no bias in selection were involved.

Since the length of an experiment does not increase the degrees of freedom, the possibility exists that such experiments might be conducted for short periods without impairing the results. Should a 4-week period prove adequate, then more replications could be made with the same total effort that would be required for a small number of lots extending over many periods.

EXPERIMENTS WITH RE-RANDOMIZATION

Assuming one wishes to compare two diets using six lots or troughs, three may be assigned to each diet at random. Then, for the first period, the growth might be tested as follows:

number of lots	6
degrees of freedom	
total	5
diets	1
error	4

If, at the end of the first period, the previous assignment of diets were discontinued and a new randomization made for a second period, then growth of the fish on a particular diet during the second period would depend on that during the first period in a random manner. In other words, it could be treated as independent. If the experiment covered three periods and the troughs were reassigned at the start of each period, the analysis would be as follows:

number of items	18
degrees of freedom	
total	17
diets	1
periods	2
error	14

The increase in the degrees of freedom for error is an indication that the sensitivity of the test may have been increased considerably.

Two considerations involved in this method require comment. First, if one of the diets tested were very poor and the other very good, fish in a trough which happened to have the poor diet in Period 1

and the good diet in Period 2 might make a superior growth in the second period as compared with those in another trough which happened to have the good diet during both periods. If this were true, then, for fish getting the same diet during the second period, the variation in growth rate between the two periods might be so great as to nullify any beneficial results of the re-randomization.

A single experiment conducted by the writer indicated that trout quickly respond to a diet change, so that the time required for readjustment following a re-randomization of diets is too small to influence an experiment conducted for 4-week periods.

Second, growth should be measured in appropriate units. A detailed discussion is beyond our present purpose. It appears that, unless the total duration of an experiment is very short, the unit selected should be such that the mean and variance for each period are independent. For attained weights, mean and variance are believed to be proportional. It is also desirable that the unit of growth measurement be independent of fish size. As suggested earlier, either (1) the increment of the cube root of the average weight or (2) the length as converted from weight are free of most of the objectionable features from a statistical point of view. For growth experiments covering several successive periods, trial of one of these measures is strongly urged.

Once the method of conducting experiments for short periods is established, more complex designs can be used. For example, experiments are often conducted in troughs arranged in series of three. A number of such series may be used, but it is well known that growth is greatest in the upper trough of such a series and least in the last trough. The methods of "randomized blocks" may be applied in this case to increase precision.

Randomized blocks might also apply where insufficient trout of a particular strain or even species were available. In this case one strain might be assigned to a group of troughs, and a second to the remainder.

If, for such an experiment, there is reason to expect marked differences in the several series, the Latin Square design might be useful. The use of Latin Square under conditions paralleling a trout growth experiment, in series of troughs and for successive periods, is described by Paterson (1939). Additional experimental designs are well treated by Snedecor (1957) and others.

The randomized block, the Latin Square and other complex designs are intended to recover as much information as possible from an experiment in which the experimental materials (such as fish or troughs)

vary among themselves. Such designs often secure supplementary information also, such as a measure of the differences in growth in the several troughs of a series. For greatest precision, however, there is no substitute for a large number of replications under uniform conditions, such as troughs with individual water supplies and fish of the same strain and size.

LONG-TERM EXPERIMENTS WITHOUT RE-RANDOMIZATION

The method of re-randomizing diets at the end of short periods is often not applicable when the diets under test involve possible deficiencies whose effects may require several weeks to become apparent. In such experiments, the mortality and growth records must cover long periods to show the effect of the deficiency. A method will be described which seems more sensitive than the usual tests for comparing growth under these circumstances.

It has already been pointed out that, in long-term experiments, successive periods do not increase the number of degrees of freedom. For each trough of fish used, only one measure of growth may be employed in the analysis. Considerable latitude is permitted, however, in selecting the measure of growth.

TABLE 7. ANALYSIS OF VARIANCE OF FINAL ATTAINED WEIGHTS AS A MEASURE OF THE COMPARATIVE GROWTH OF BROOK TROUT FED DIFFERENT DIETS

Data (final weights in grams)*

Meat diet	Meat and dry-food diet
16.1	18.6
17.6	17.1
15.9	18.3
18.2	17.3

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	Value of F
Total	7	697		
Diets	1	153	153	
Error	6	544	91	1.68

* Average for each lot.

Phillips *et al.* (1940) presented data for eight lots of brook trout during 12 successive 2-week periods. Of the eight lots, four were fed a meat diet and four a meat and dry-food diet. These data may be used to compare the growth-producing abilities of the two diets. Three measures of growth will be evaluated to determine the relative sensitivity of each.

In animal nutrition, final attained weights are often used to compare growth. These data for the brook trout are tabulated and compared by analysis of variance in Table 7. The resultant value of F is not significant.[3]

A second measure of growth sometimes employed is the average of the percentage gains in weight for the individual periods. For the same lots, these figures are tabulated and compared by analysis of variance in Table 8. This appears to be a more sensitive measure-

Table 8. Analysis of Variance of Average Percentage Gains in Weight as a Measure of the Comparative Growth of Brook Trout Fed Different Diets

Data (weight gains in per cent)§	
Meat diet	Meat and dry-food diet
33	35
34	34
33	35
34	34

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	Value of F
Total.....	7	4		
Diets.....	1	2	2	
Error.....	6	2	0.33	6.06*

* Significant at the 5 per cent level.
§ Average for the several periods for each lot.

ment than final attained weight. The difference in the growth rate is shown to have been barely significant.

[3] In Tables 7, 8 and 10: $F_{.05} = 5.99$; $F_{.01} = 13.74$

TABLE 9. INCREASE IN WEIGHT FOR ONE LOT OF BROOK TROUT DURING TWELVE 2-WEEK PERIODS AND CALCULATION OF REGRESSION COEFFICIENT

Date	Mean weight in grams	Period ending (X)	Cube root of mean weight (Y)
April 12	0.54	0	0.814
April 26	0.82	1	0.936
May 10	1.18	2	1.057
May 24	1.68	3	1.189
June 7	2.40	4	1.339
June 21	3.33	5	1.493
July 5	4.35	6	1.632
July 19	5.75	7	1.792
August 2	7.15	8	1.926
August 16	9.12	9	2.089
August 30	11.30	10	2.234
September 13	13.20	11	2.363
September 27	16.10	12	2.525

Regression coefficient: $\frac{Sxy}{Sx^2} = 0.144$

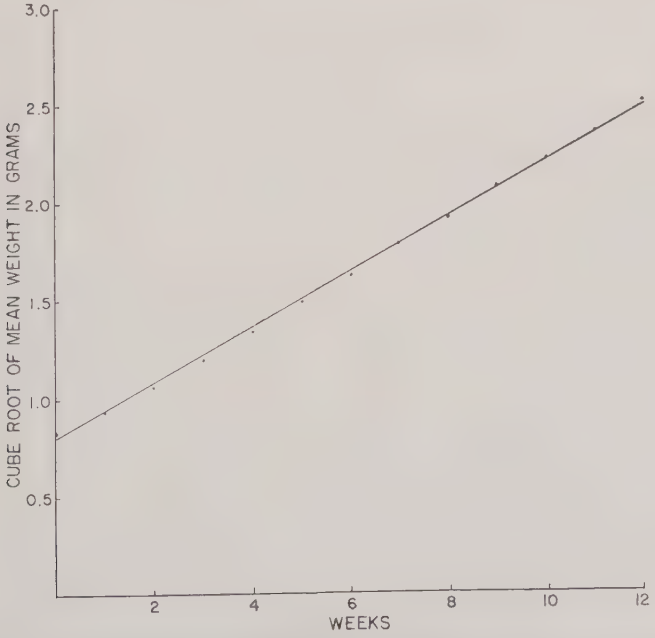

Figure 7. Rate of growth of a sample lot of brook trout based on the increase in the cube root of the weight.

Table 10. Analysis of Variance of Regression Coefficients for Increase in Weight as a Measure of the Comparative Growth of Brook Trout Fed Different Diets

Data (regression coefficients)§	
Meat diet	Meat and dry-food diet
0.144	0.155
0.151	0.152
0.145	0.155
0.149	0.153

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	Value of F
Total.....	7	124		
Diets.....	1	84.5	84.5	
Error.....	6	39.5	6.58	12.8*

* Significant at the 5 per cent level.
§ Value for each lot.

A third measure of growth uses the cube root of the weight.[4] This value is computed for each period for each lot, and by the methods of linear regression the slope of the best-fitting straight line for each lot is determined. The slope, expressed as the regression coefficient, is used as a measure of growth, i.e., the increase in the cube root of the average weight per period. The method used in calculating the regression coefficient for one lot (No. 400) is illustrated in Table 9.

The values for the cube root of the mean weight for the same lot are plotted in Figure 7.

The regression coefficients for the other lots are similarly calculated, and the figures for all eight are tabulated and compared by analysis of variance in Table 10. For convenience, the values for the coefficients are treated as whole numbers, e.g., 144, in the analysis of variance.

The analysis shows that in this case the cube root provided a value of F almost significant at the 1 per cent level. There are several

[4] As pointed out earlier, $W = 0.0004055L^3$; therefore, $\sqrt[3]{W} = 0.0740L$, i.e., the cube root of the weight varies directly with length.

mathematical reasons why this measure of growth might be more sensitive in trials of this type.

The data were obtained at a constant water temperature. Introduction of a variable water temperature would require a more elaborate analysis. Two such analyses using the cube root of the average weight and adjusting for differences in water temperature were reported by Haskell *et al.* (1952, 1956).

Another method applicable under variable water temperatures employs the temperature units already described. Statistical treatment is very similar to that applied to the Cortland data. The steps to be taken are:

1. Tabulate length (or cube root of weight) *vs.* temperature units, using data for the end of each time period.
2. Calculate regression of length in relation to temperature units.
3. Evaluate regression coefficient as a measure of growth by analysis of variance.

Use of this method should, perhaps, await a more firm confirmation of the temperature-unit system.

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